Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, D.C. 20554

In the Matter of	)	
	)	
Promoting Interoperability in the 700 MHz Commercial Spectrum	))	WT Docket No. 12-69
	)	
Interoperability of Mobile User Equipment Across Paired Commercial Spectrum Blocks in the 700 MHz Band	)))	RM-11592 (Terminated)

COMMENTS OF QUALCOMM INCORPORATED

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I. INTRODUCTION AND SUMMARY.

QUALCOMM Incorporated ("Qualcomm") respectfully submits these comments in response to the Federal Communications Commission's ("Commission" or "FCC") above-captioned Notice of Proposed Rulemaking ("NPRM"). Qualcomm is a multi-mode, multi-band chip provider for wireless devices including cell phones, tablets, and e-readers. Qualcomm works with virtually every mobile phone carrier and manufacturer in the world with the goal of providing chipsets that incorporate as many technologies as possible, that support as many frequency bands as possible, and that do so with the best achievable performance. The company innovates constantly and spends billions of dollars every year to achieve this goal.

Qualcomm operates in a hyper-competitive environment, as carriers, device manufacturers, and rival chip vendors all race to deliver the best, most appealing, and lowest-cost devices. The advent and rapid deployment of LTE has created several challenges for Qualcomm. This is the case because the proliferation of LTE bands requires Qualcomm to design chips that support multiple bands, with an almost endless set of band-combination permutations, and that also support legacy 3G and 2G technologies. LTE has been standardized for at least 36 frequency bands around the world.[1] In the United States alone, operators have deployed or plan to deploy LTE in the:

- 700 MHz 3GPP bands (Band Classes 12, 13, 14, 17);
- 850 MHz cellular band (Band Class 5);
- Original PCS band (Band Class 2);
- PCS Block G (Band Class 25);
- AWS-1 band (Band Class 4);
- Potential AWS-4 band (Band Class 23);
- Original 800 MHz iDEN band (Band Class 26); and
- BRS band (Band Class 41).

Even more bands are in the pipeline, such as those that will result from the (pending) voluntary incentive auction of TV spectrum.

Furthermore, the impending launch of "carrier aggregation" technology, whereby carriers bind one band to another to create wider channels to support enhanced service, means that carriers are seeking to bind LTE bands to one another, adding another layer of complexity for Qualcomm. To provide chips that support all of these bands and band combinations, Qualcomm is aggressively working with carriers and manufacturers to empower a greater level of interoperability than has ever existed for carriers and customers, involving the huge diversity of band combinations listed above.

Against this backdrop, Qualcomm appreciates the opportunity to assist the Commission as it evaluates whether the customers of Lower 700 MHz B and C Block licensees would experience harmful interference if the FCC were to mandate that carriers with Lower 700 MHz B

[1] *See* Radio-Electronics.com, LTE Frequency Bands & Spectrum Allocations, http://www.radio-electronics.com/info/cellulartelecomms/lte-long-term-evolution/lte-frequency-spectrum.php (last visited June 1, 2012).

and C Block licenses use Band 12 rather than Band 17 in their devices and network equipment.[2] Because Qualcomm supplies chips for use in LTE-3G-2G devices, but not chips used in LTE base stations, these comments will address interference to devices, not to base stations.

The Lower 700 MHz band is a tremendously challenging interference environment because it places high-power operations in close proximity to lower-power operations and high-power downlink signals immediately adjacent to low-power uplink signals. Specifically, lower-powered Commercial Mobile Radio Service ("CMRS") device operations in the A Block (transmitting at Channel 52 and receiving at Channel 57), B Block (transmitting at Channel 53 and receiving at Channel 58), and C Block (transmitting at Channel 54 and receiving at Channel 59) must occur in the face of high-power signals transmitted from the E Block (Channel 56) and TV Channel 51.[3]

To address the risk that the high-power E Block and Channel 51 signals would cause harmful interference to consumer devices operating on the B and C Blocks, 3GPP, an independent, consensus-governed standards organization, created Band 17.[4] The operative difference between Band 17 (which applies to the B and C Blocks) and Band 12 (which applies to the A, B, and C Blocks) is the filtering requirements that devices on each band must meet

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2 *Promoting Interoperability in the 700 MHz Commercial Spectrum*, Notice of Proposed Rulemaking, ¶¶ 5, 32, WT Docket No. 12-69, RM-11592 (rel. Mar. 21, 2012) ("NPRM"). Qualcomm understands that the interference that Lower A block licensees will surely suffer due to E Block and Channel 51 signals is beyond the scope of this proceeding.

3 The FCC allows high-power operations in the E Block except for the E Block licensees held by AT&T Mobility. *Application of AT&T Inc. & Qualcomm Inc. for Consent to Assign Licenses & Authorizations*, Order, ¶ 62, WT Docket No. 11-18 (rel. Dec. 22, 2011) ("AT&T-Qualcomm Order").

4 *See, e.g.*, 3rd Gen. P'ship Project (3GPP), Technical Specification Group Radio Access Network; Evolved Universal Terrestrial Radio Access (E-UTRA) User Equipment (UE) radio transmission and reception (Rel. 10), 3GPP TS 36.101 V.10.4.0 (2011-09), at Table 15.5-1, *available at* ftp://ftp.3gpp.org/specs/2011-09/Rel-10/36_series/36101-a40.zip ("3GPP TS 36.101").

under 3GPP standards. Band 17 requires a narrower filter than does Band 12, in an effort to reduce the threat of interference from the E Block and Channel 51.[5] The narrower Band 17 filter provides far more attenuation of E Block and Channel 51 signals than the Band 12 filter by using the two A Block frequencies (Channels 52 and 57) as *de facto* 6 MHz guard bands. Because Band 12 has no such guard bands, current filtering technology can provide virtually no attenuation of the E Block or Channel 51 signals.

Qualcomm's tests and analyses demonstrate that consumer devices operating on the Lower B and/or C blocks using the Band 12 filter will suffer harmful interference from E Block and Channel 51 signals, while the Band 17 filter provides these devices with an effective defense. More specifically, these comments will show that without the Band 17 filter:

- High-power E Block signals would cause blocking interference to consumer devices seeking to receive a 5 MHz signal on the B Block or a 10 MHz signal on the B and C Blocks;

- High-power E Block signals would cause intermodulation interference to consumer devices seeking to receive a 5 MHz signal on the B or C Block or a 10 MHz signal on the B and C Block; and

- Channel 51 television signals would cause reverse intermodulation interference to consumer devices seeking to receive a 5 MHz signal on the C Block or a 10 MHz signal on the B and C Blocks.

Qualcomm's tests and analyses also demonstrate that the remediation strategies on which the FCC seeks comment in the NPRM would not effectively solve these interference problems.

Given the significant technical challenges associated with the Lower 700 MHz band, Qualcomm continues to work with carriers and manufacturers to find solutions. Since October 2011, Qualcomm has offered chips for use by Lower A Block licensees that include support for LTE on Band 12 plus other 3G or 4G bands (including cellular, PCS, and AWS-1). These chips

[5] *See, e.g.*, 3GPP TS 36.101, ¶ 7.6.2.

can support only two ports for bands below 1 GHz, and therefore cannot support both two 700 MHz bands and the 850 MHz cellular band. They can support either Band 12 or Band 17, but not both. To attempt to work around this limitation, Qualcomm offered Lower A Block licensees chips that would support an external switch to enable a single port to support both Band 12 and Band 17, but the performance of devices using this solution would be degraded, so they declined such a solution. In any event, as discussed below, the Qualcomm chips that include support for Band 12 do not solve the breadth of the harmful interference problems present in the Lower 700 MHz band, and can also create significant device limitations. Thus, mandating that Lower B and C block licensees use Band 12 instead of Band 17 will impose substantial risks of serious service degradations.

Qualcomm has accelerated development of its next generation RF chip, the WTR1605L. This new RF chip will support a total of seven frequency bands—three below 1 GHz, three higher bands, and one very high band (such as 2.5 GHz).[6] Qualcomm is just beginning the transition to this chip, which is occurring in conjunction with its transition to 28 nanometer chips. The first chipset using the WTR1605L is the MSM-8960. Qualcomm is currently facing supply constraints with respect to its 28 nanometer chips, including the MSM-8960. Qualcomm nonetheless expects that the first MSM-8960 chips supporting Band 12 based on the WTR1605L will begin shipping to device manufacturers in July of this year, and the first devices based on the MSM-8960 should reach store shelves by the end of this year. Qualcomm has informed Lower A Block licensees that Qualcomm will provide software to device manufacturers to

[6] Press Release, Qualcomm Inc., Qualcomm Introduces 28 nm Mass Market LTE/DC-HSPA+ Chipsets for Mobile Broadband Products (Feb. 14, 2011) http://www.qualcomm.com/media/releases/2012/02/14/qualcomm-introduces-28nm-mass-market-ltedc-hspa-chipsets-mobile-broadband-.

enable them to do the necessary integration (including addition of the necessary filters) and testing to support LTE roaming on Bands 13 or 17, and/or 25 (Sprint's PCS G block).

Because the transition to the WTR1605L and 28 nanometer chips is in its infancy, it would be inappropriate for the FCC to mandate their use. Furthermore, as shown above, carriers holding Lower A Block or other 700 MHz spectrum have many different band combinations to choose from to meet their customers' interoperability needs, both within the 700 MHz band and between any of the long list of other 4G bands. A Band 12/17 combination is merely one such combination, and it would be inappropriate for the FCC to mandate that carriers must make this one combination available on every consumer device.

In fact, Qualcomm's innovations and ongoing work with carriers and manufacturers demonstrate that there is no need for any FCC mandate.[7] Because of the difficult interference challenges described herein, the fact that existing technology does not offer a solution to these challenges, and Qualcomm's ongoing innovation and collaboration with all carriers and manufacturers, the Commission should not require mobile equipment to be capable of operating over all paired commercial spectrum blocks in the Lower 700 MHz band.

II. Effects of High-Power E Block Signals on Consumer Devices Seeking To Receive B and C Block Signals.

FCC rules permit E Block (Channel 56) licensees to operate base stations at high power—up to 50 kW.[8] Qualcomm's analysis shows that without a Band 17 filter, such high-power operations on Channel 56 could cause both blocking interference and intermodulation

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7 *See*, *e.g.*, Press Release, Clearwire Corporation, Clearwire Expands LTE Choices in North America (May 8, 2012) http://finance.yahoo.com/news/clearwire-expands-lte-choices-north-100000784.html.

8 47 C.F.R. § 27.50(c)(7).

interference in mobile devices used by the customers of Lower B and C Block licensees. As a result, these customers could experience degraded or lost coverage in numerous locations in every market where E Block licensees launch high-power operations around the country. Unfortunately, the interference mitigation techniques suggested by Lower A Block licensees will not adequately protect these consumers.

A. Without the Band 17 Filter, High-Power E Block Signals Would Cause Blocking Interference To Consumer Devices Seeking To Receive B Block Signals.

Degradation of a device's ability to receive and process a desired signal due to strong nearby unwanted signals is termed "blocking interference."[9] The stronger an undesired signal is, and the closer its frequency is to the desired signal, the greater the threat of interference.[10] In the Lower 700 MHz band, an E Block signal's high power and proximity to consumer devices' B Block receive band creates a serious threat of harmful blocking interference.

Consumer devices may accurately receive an intended signal in the presence of an undesired signal up to a certain level. Generally applicable 3GPP specifications—not those specific to Band 12 or 17—define this level.[11] 3GPP TS 25.101 contains the requirements for 3G networks and 3GPP TS 36.101 contains the requirements for 4G networks. Suppliers of cellular devices around the world adhere to these levels, and the capabilities of consumer devices match these requirements closely. As summarized in Table 1, these 3GPP requirements specify that the receiver in a consumer device will operate properly in the presence of: (1) a -52 dBm (5 MHz bandwidth) signal at ± 5 MHz from channel center; (2) a -56 dBm (5 MHz bandwidth)

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9 *See* NPRM, ¶ 32; *see also* 3GPP TS 36.101, ¶ 7.6.

10 *See, e.g.*, 3GPP TS 36.101, ¶¶ 7.5 (adjacent channel), 7.6.1 (in-band blocking), and 7.6.2 (out-of-band blocking).

11 *See* 3GPP TS 36.101, ¶ 7.6.

signal at ± 10 MHz from channel center; or (3) a -44 dBm (5 MHz bandwidth) signal at ≥15 MHz from channel center.

Table 1

Offset Frequency (MHz)	Maximum Blocker Level (dBm)
±5	-52
±10	-56
≥15	-44

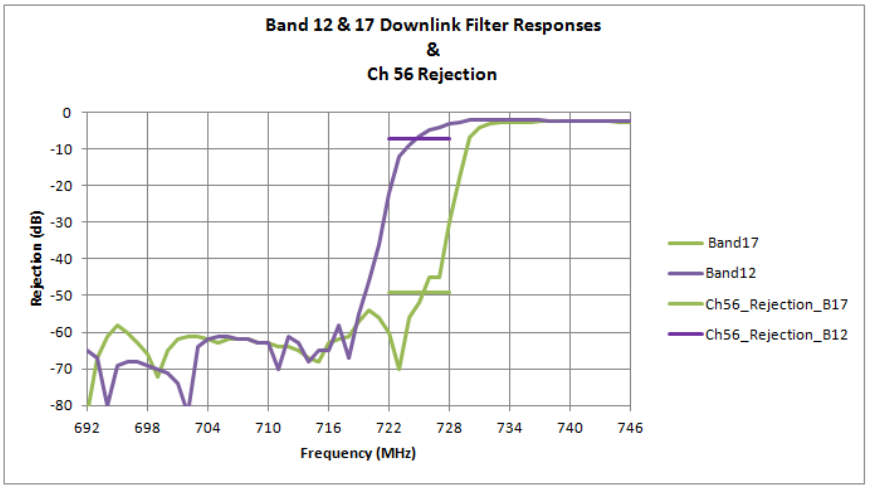
The E Block signal (on Channel 56) is approximately 12 MHz from the signal a B block device seeks to receive on Channel 58. So the device, when attempting to receive a B block signal, can suffer harmful interference when it experiences an E Block signal higher than -56 dBm. A properly designed filter, however, can prevent blocking interference by ensuring that the received E Block power is below this level. Equipment manufacturers and carriers therefore worked together in 3GPP to design the Band 17 filter specification to achieve this goal. 3GPP member companies agreed upon this new approach because devices operating according to the Band 12 specification simply could not avoid Channel 56 blocking with currently available filtering technology.

In order to analyze the performance of the Band 17 and Band 12 filters' ability to reduce E Block blocking interference, Qualcomm examined published filter performance specifications from Taiyo Yuden and Epcos, among others,[12] both of which are first-tier suppliers of currently available or production-ready filters. As illustrated in Figure 1 below, performance for these

[12] Qualcomm reviewed performance characteristics data for Tier 1 filters from Avago, Epcos, MuRata, Taiyo Yuden, and Triquint. It selected Epcos and Taiyo Yuden filters as representative examples for its analysis. Figure 1 is based on the Taiyo Yuden Band 12 and 17 filters.

filters reveals that the Band 12 filter provides 7 dB of E Block rejection, while the Band 17 filter provides 49 dB of E Block rejection. Thus, the extra 42 dB means that the Band 17 filter provides 15,849 times more attenuation of the high-power E block signal than the Band 12 filter can provide.

Figure 1



Applying these filter performance values and the generally accepted 3GPP maximum blocker levels discussed above, Qualcomm analyzed blocking interference from the E Block. Table 2 subtracts the E Block rejection specified for each filter from three possible E Block received signal levels, and then subtracts these results from the 3GPP -56 dBm maximum blocker level. This yields the amount of E Block signal power experienced by the receiver above or below the maximum blocker level—the blocking margin. The Band 12 filter does not reject high-power E Block signals enough to meet the 3GPP maximum blocker level specification when received power is -49 dBm or higher, and will not prevent interference to B Block receivers.

Table 2

Ch 56 Level @ UE Antenna Port (dBm)	Band 12 Duplexer		Band 17 Duplexer	
	Ch58 Filtered Level (dBm)	Resulting Rx Condition	Ch58 Filtered Level (dBm)	Resulting Rx Condition
-10	-17	Receiver severely blocked -39dB margin	-59	+3dB margin No Blocking
-20	-27	Receiver severely blocked -29dB margin	-69	+13dB margin No Blocking
-30	-37	Receiver severely blocked -19dB margin	-79	+23dB margin No Blocking
-40	-47	Receiver blocked -9dB margin	-89	+33dB margin No Blocking
-50	-57	+1dB margin No Blocking	-99	+43dB margin No Blocking

Qualcomm confirmed these results by examining the same interference environment from a different perspective. Table 3 analyzes the level of desensitization that a consumer device's receiver would experience at different E Block signal levels (rather than calculating the blocking margin as Qualcomm did in Table 2). Qualcomm again started with several possible received E Block power levels, subtracted the E Block rejection specified for each filter from these power levels, and then calculated the level of desensitization that a device's receiver would experience at each filtered power level.[13]

[13] To calculate desensitization, Qualcomm assumed 43 dB of Channel 56 rejection, which provides a margin beyond the 3GPP standard of 35 dB. *See* 3GPP TS 36.101, ¶ 7.6.1 (intended signal at -91 dBm, blocker at -56 dBm, yielding blocker rejection of 35 dB). For example, for a Channel 56 received power level of -40 dBm, Qualcomm added the Band 12 filter rejection (7dB) and the blocker rejection of 43 dB, and calculated that the device could tolerate -90 dBm of interference. Assuming a UE noise floor of -101.47 dBm (6 dB noise figure) and a Combined Noise and Interference level of -89.70 dBm, Qualcomm calculated the level of desensitization (the difference between Combined Noise and Interference, and the UE Noise Floor) to be 11.77 dB.

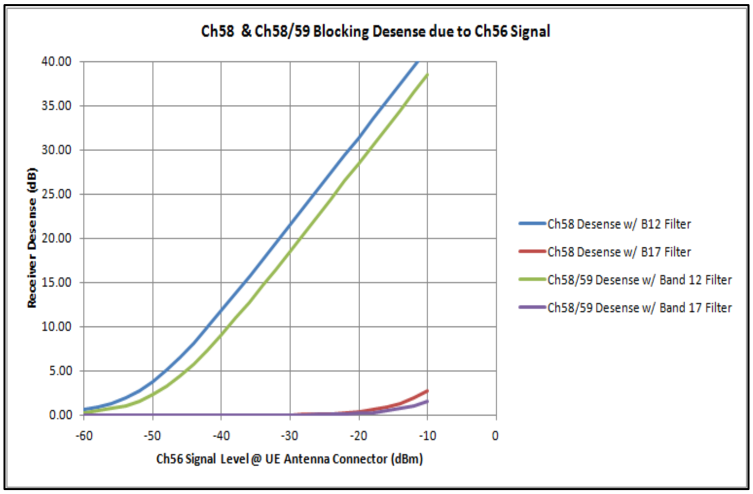
Table 3

Ch 56 Level @ UE Antenna Port (dBm)	Band 12 Duplexer			Band 17 Duplexer		
	Level after filter (dBm)	Ch58 Desense (dB)	Ch58/59 Desense (dB)	Level after filter (dBm)	Ch58 Desense (dB)	Ch58/59 Desense (dB)
-20	-27	31.5	28.5	-69	0.37	0.19
-30	-37	21.5	18.6	-79	0.04	0.02
-40	-47	11.8	9.1	-89	0.00	0.00
-50	-57	3.81	2.32	-99	0.00	0.00

Table 3 shows that the Band 12 filter will not reject high-power E Block signals enough to prevent blocking interference to begin to degrade service for B Block receivers when received power is as low at -50 dBm.[14] Figure 2 plots these same calculations for a larger group of received E Block power levels. It shows, for example, that a consumer device operating on the B Block with a Band 12 filter, trying to receive a 5 MHz signal on Channel 58, will experience 3 dB of receiver desensitization when it receives a -51.5 dBm E Block signal at its antenna port and 6 dB of desensitization with a -46.7 dBm E Block signal. A consumer device operating on the B and C Blocks, with a Band 12 filter, trying to receive a 10 MHz signal on Channels 58 and 59 will experience 3 dB of desensitization with a -48.5 dBm E Block signal and 6 dB of desensitization with a -43.7 dBm E Block signal.

14 The fact that desensitization occurs with a -50 dBm received signal, which as shown in Table 2 would not violate the 3GPP maximum blocking level, demonstrates that blocking interference begins to degrade service even before the 3GPP maximum blocking level is reached.

Figure 2



Three dB of desensitization establishes the threshold where E Block interference becomes the dominant performance concern, undermining the device's operations, rendering the device unable to receive a signal at the edges of cellular coverage areas and in many indoor environments. In effect, an additional 3dB of desensitization shrinks the coverage area of existing cells from the area that the cells would otherwise cover adequately. Six dB of desensitization doubles (compared to the 3 dB desensitization level) the negative impact on the device, more severely shrinking the coverage areas of cells and resulting in dropped calls, service interruptions, and lost system capacity.

Qualcomm's analysis reveals that consumers would encounter E Block power levels across the country that are high enough to cause 6 dB or more of device desensitization. Qualcomm has insight into power levels in these frequencies because of its experience building and operating its Lower D Block (Channel 55) licenses for its now-discontinued MediaFLO network.[15] MediaFLO used transmitters operating at up to 50 kW, the same power limit that governs the Lower E Block.[16]

In order to engineer and manage the MediaFLO network, the company performed drive testing to take power-level measurements in many major cities. For example, as depicted in Figures 3 and 4, these tests found numerous locations throughout the Dallas and Phoenix areas at which the Channel 55 received power levels were -51 dBm or higher, which would cause harmful interference to B Block devices using Band 12 filters. These maps show areas where Qualcomm measured power levels high enough to produce desensitization to consumer devices of: (1) 6 dB or more (red dots), 3-6 dB (yellow dots), and less than 3 dB (green dots). The areas of interference are not isolated or remote. They extend across these regions and often occur in the more densely populated areas of the network where operators need additional capacity most.

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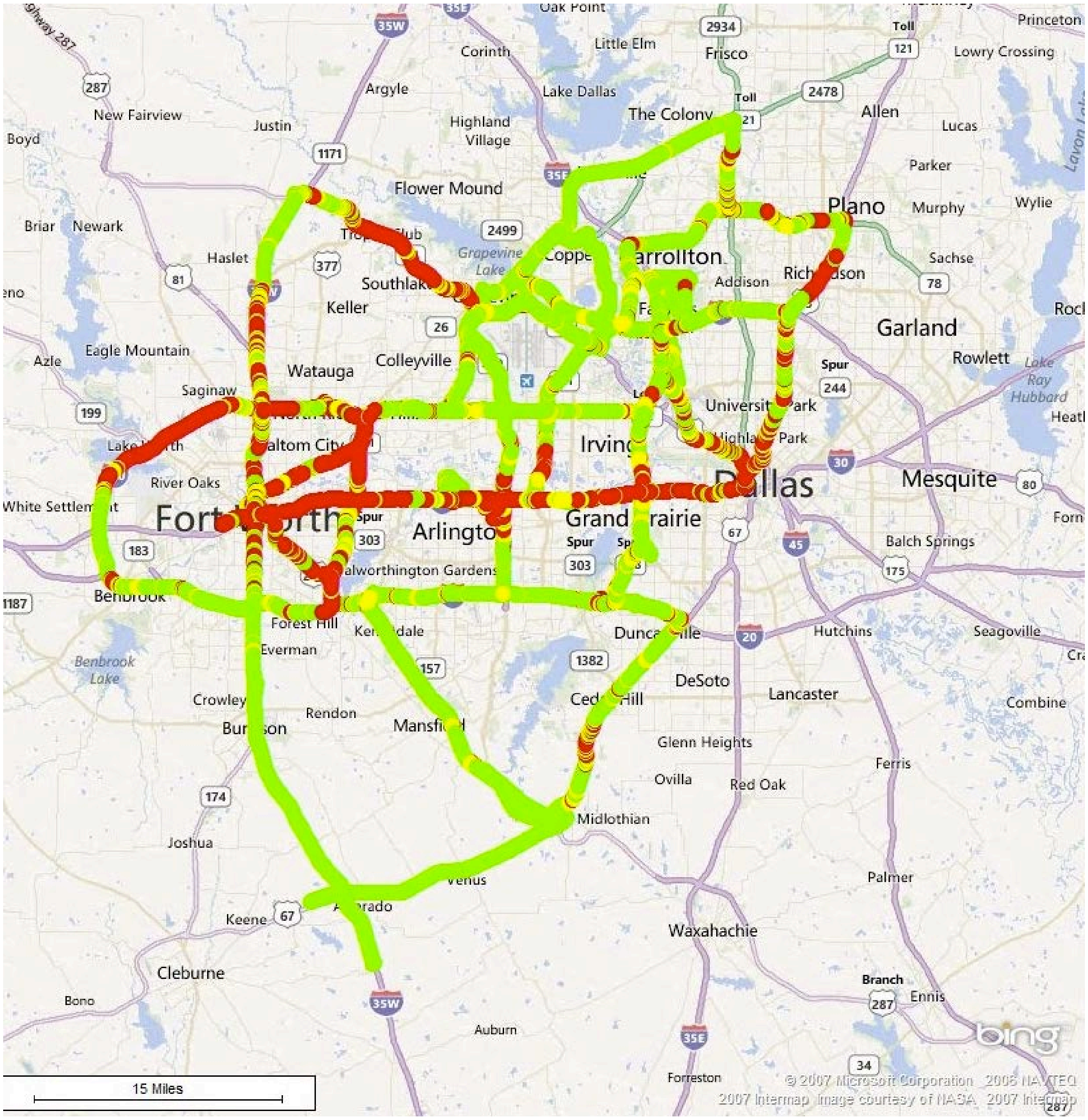
15 MediaFLO was a Qualcomm service that delivered video programming to mobile devices via 50,000 Watt transmitters across the country. Qualcomm held both D Block and E Block licenses for this business, but only operated the service on the D Block. Qualcomm discontinued MediaFLO in 2010 and transferred its licenses to AT&T Mobility.

16 *See, e.g.*, AT&T-Qualcomm Order, ¶ 59.

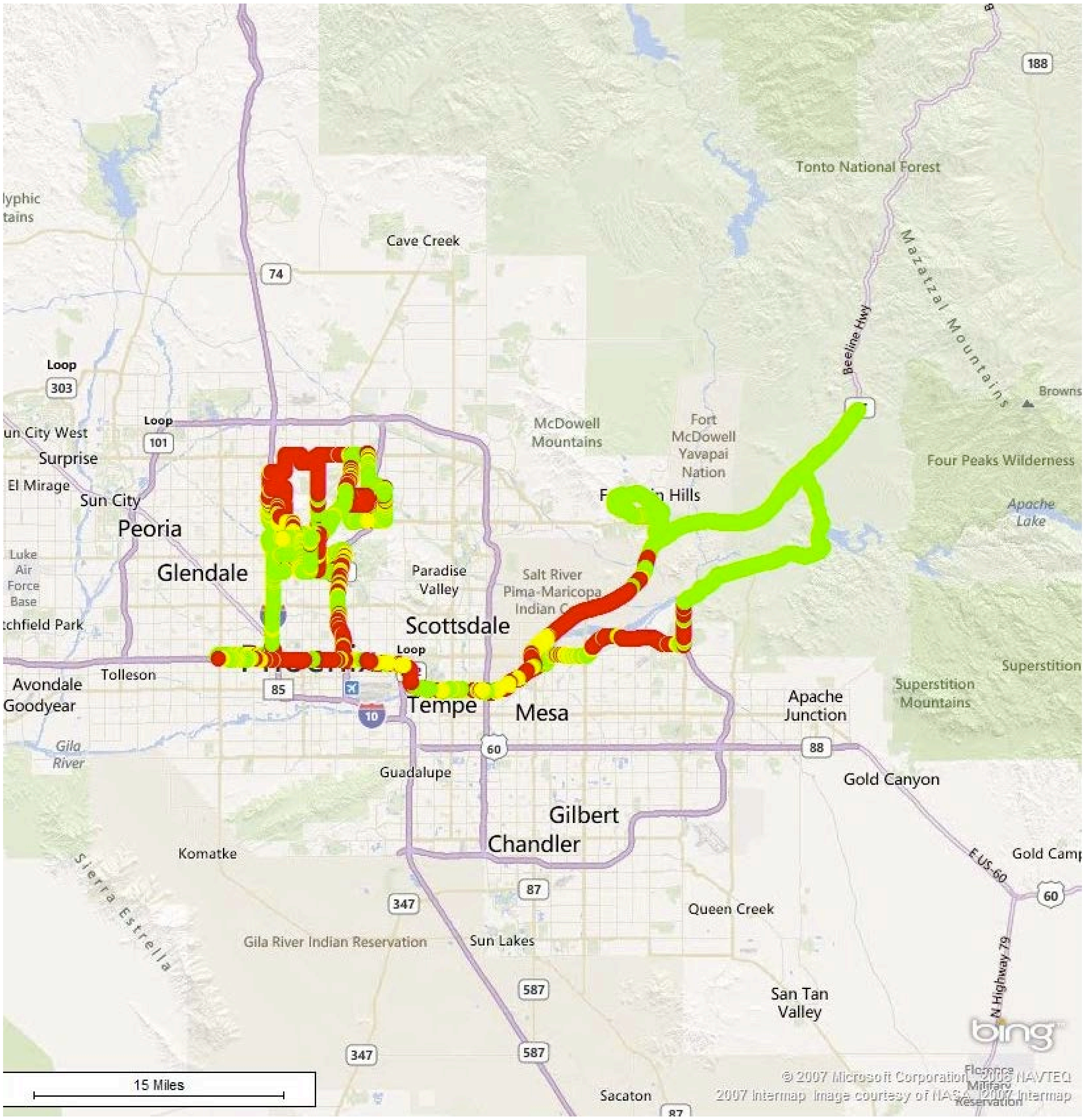
Figure 3
Channel 55 Received Power Measurements (Re: 5 MHz Signal)
Dallas/Fort Worth, Texas



Red: Above -46.8 dBm

Yellow: -51 to -46.8 dBm

Figure 4
Channel 55 Received Power Measurements (Re: 5 MHz Signal)
Phoenix, AZ

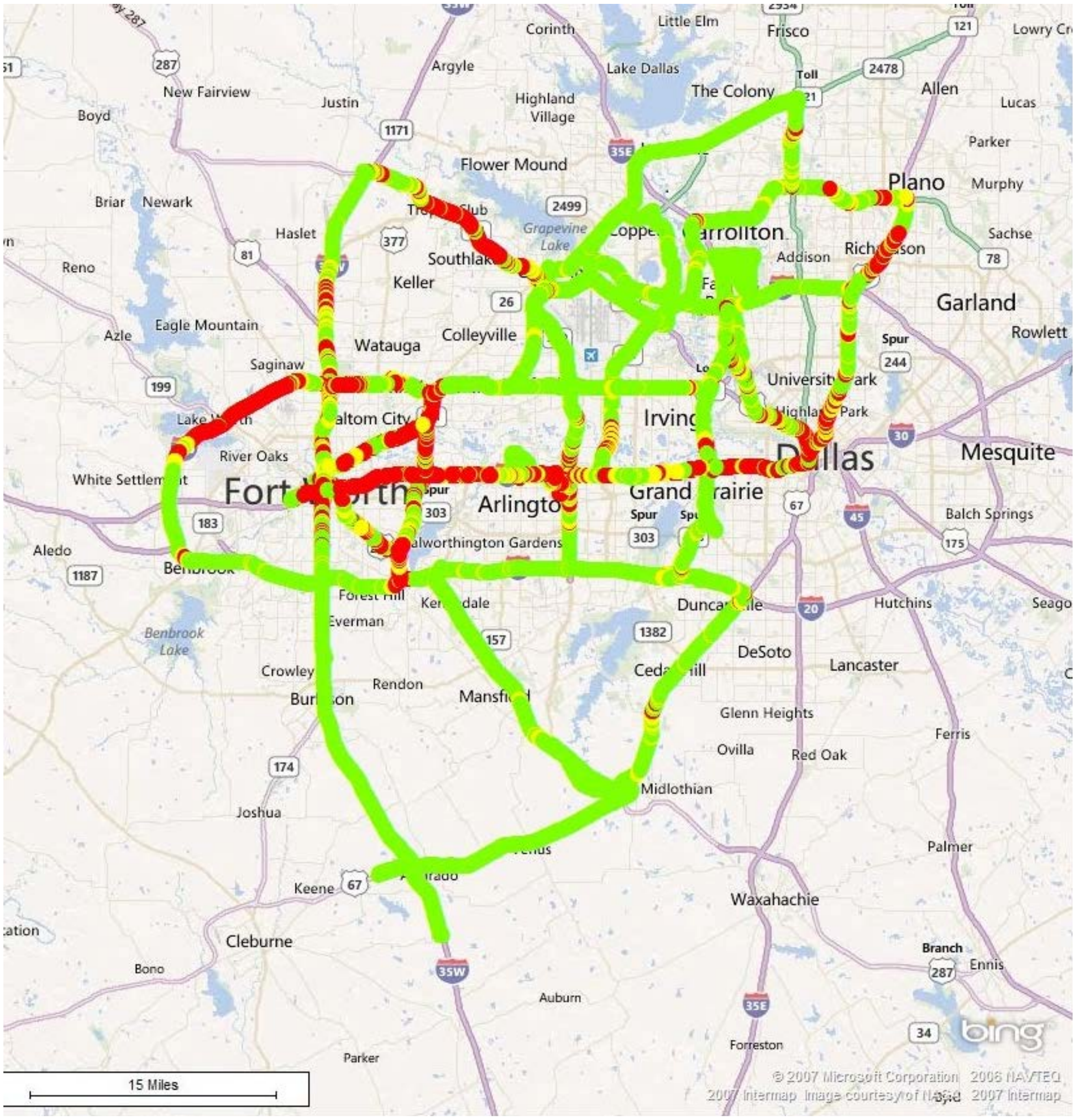


Red: Above -46.8 dBm

Yellow: -51 to -46.8 dBm

Likewise, as Figures 5 and 6 verify, power levels of -48.5 dBm or stronger were also seen throughout the Dallas and Phoenix areas. Thus, there would be significant blocking interference caused to devices using a Band 12 filter and trying to receive a 10 MHz signal on the Lower B and C Blocks (on Channels 58 and 59).

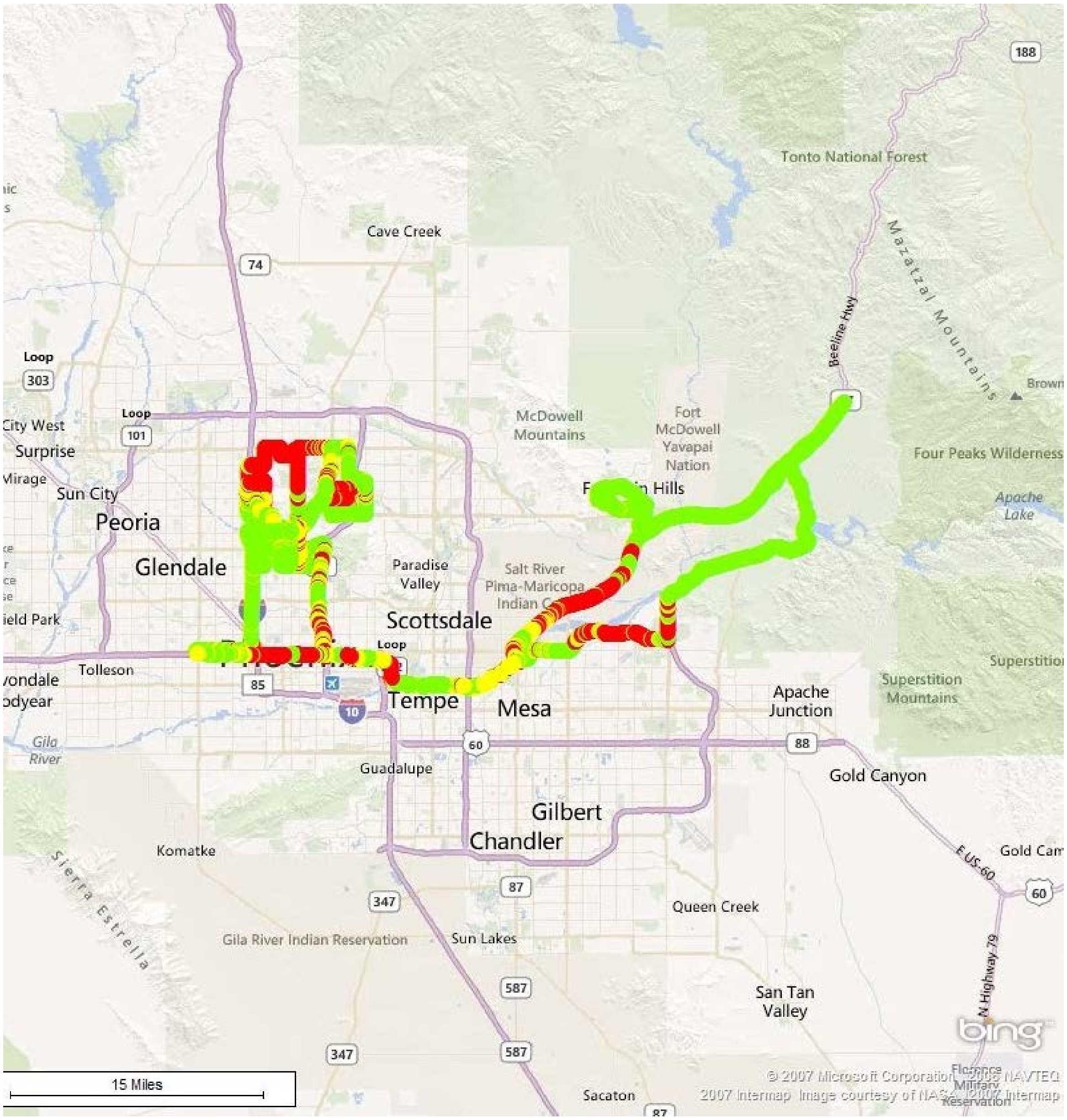
Figure 5
Channel 55 Received Power Measurements (Re: 10 MHz Signal)
Dallas/Fort Worth, TX



Red: Above -43.8 dBm

Yellow: -48.5 to -43.8 dBm

Figure 6
Channel 55 Received Power Measurements (Re: 10 MHz Signal)
Phoenix, AZ



Red: Above -43.8 dBm

Yellow: -48.5 to -43.8 dBm

These Channel 55 (Lower D Block) power levels are the best available evidence of the power levels consumers could actually face from high-power Lower E Block operations now permitted under the FCC rules governing the Lower E Block. Prior to its transfer of its Lower D Block licenses, the FCC-permitted power levels for MediaFLO frequencies were identical to those that apply to the Lower E Block[17]—and the propagation characteristics of signals at Lower D Block at Channel 55 and the Lower E Block at Channel 56 are essentially the same.[18] Thus, in considering whether to impose any mandate, the Commission should assume that the Lower E Block signals, under current FCC rules, will be at the levels Qualcomm presents herein.

In sum, Qualcomm's analysis demonstrates that in locations where consumer devices experience E Block power levels as low as -51.5 dBm for B Block systems or -48.5 dBm for B and C Block systems, they could experience harmful blocking interference. Furthermore, Qualcomm's experience with MediaFLO suggests that consumers can experience such E Block power levels throughout markets where high-power E Block base stations are deployed.

B. Without the Band 17 Filter, High-Power E Block Signals Would Cause Intermodulation Interference To Consumer Devices Seeking To Receive B and C Block Signals.

In the absence of a Band 17 filter, E Block signals will also cause intermodulation interference that will degrade consumer device performance for the customers of B and C Block licensees. Intermodulation interference occurs when the signals from at least two transmitters

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17 *See* 47 C.F.R. § 27.50(c)(7); *see also* AT&T-Qualcomm Order, ¶¶ 59-62.

18 Furthermore, unlike the bare bones experimental system in Atlanta that Vulcan Wireless has tested in the past, Qualcomm's system was fully operational, offering a far more realistic picture of the power levels that will actually be seen in a commercial deployment. *Cf. Ex Parte* Letter of Michele C. Farquhar, Counsel to Vulcan Wireless LLC, to Marlene H. Dortch, FCC, WT Docket No. 11-18, RM-11592 (filed Nov. 30, 2011) ("Vulcan Study").

combine to produce a new unintentional signal in a device's receive frequency.[19] This unintentional combined frequency is called the intermodulation product. In some cases intermodulation interference can be the result of an intermodulation product created by one out-of-band signal and a consumer device's own transmit signal. In these cases the two signals form intermodulation products in a device's processing or receiver components (*e.g.* transistors or mixers) that are non-linear (meaning that the output of these components is not linearly proportional to their input).[20] These two signals produce an intermodulation product due to the receiver's nonlinearities. This intermodulation product is spread in frequency and can fall into the device's designated receive channel. This in-channel intermodulation product reduces the sensitivity of the consumer device, potentially causing dropped calls, degraded service, and lost capacity.

Consumer devices operating in either the Lower B or C Blocks alone, or using the combined B and C Blocks as a unit, are susceptible to this particular type of harmful interference, which is caused by high-power E Block signals entering the consumer device's duplexer. As illustrated in Figure 7, the device's own transmit signal, although reduced by the device's transmit/receive isolation function, also enters the device's duplexer.

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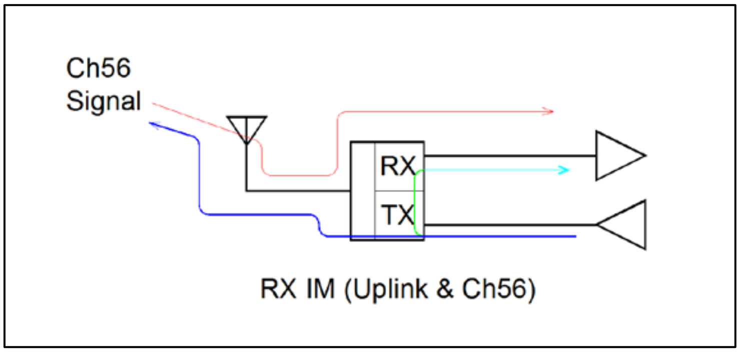
19 *See, e.g.*, Thomas H. Lee, THE DESIGN OF CMOS RADIO-FREQUENCY INTEGRATED CIRCUITS, 364-99 (1st ed. 1998).

20 *Id.*

Figure 7



Because of nonlinearities in the receiver, these two signals create an intermodulation product that extends to the frequency on which the device expects to receive its desired signal. This in-channel intermodulation product causes receiver desensitization, resulting in degraded service for the consumer. The figures below illustrate this problem.

Figure 8

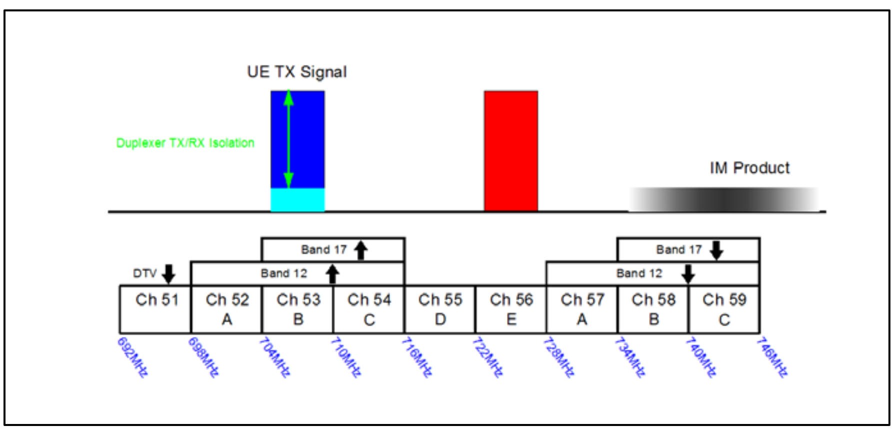


Figure 8 illustrates intermodulation interference in a consumer device with a 5 MHz wide transmission in the B Block. The device's 5 MHz transmit signal (shown in blue) and the 6 MHz wide E Block signal (shown in red) create an intermodulation product (shown in black) centered in the Lower C Block receive channel, but that spreads across and interferes with the device's B Block receive band as well.

Figure 9

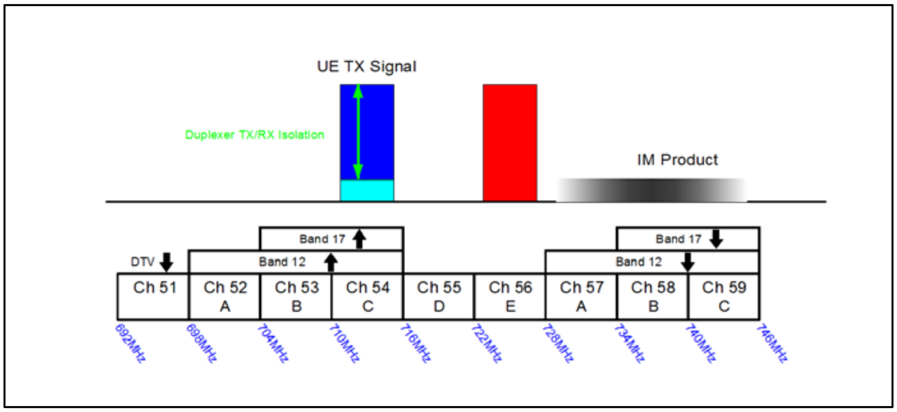


Figure 9 illustrates intermodulation interference in a consumer device with a 5 MHz wide transmission in the C Block. Here the device's 5 MHz transmit signal (shown in blue) and the 6 MHz wide E Block signal (shown in red) create an intermodulation product (shown in black) centered in the Lower B Block receive channel, but that spreads across and interferes with the device's C Block receive band as well.[21]

Figure 10

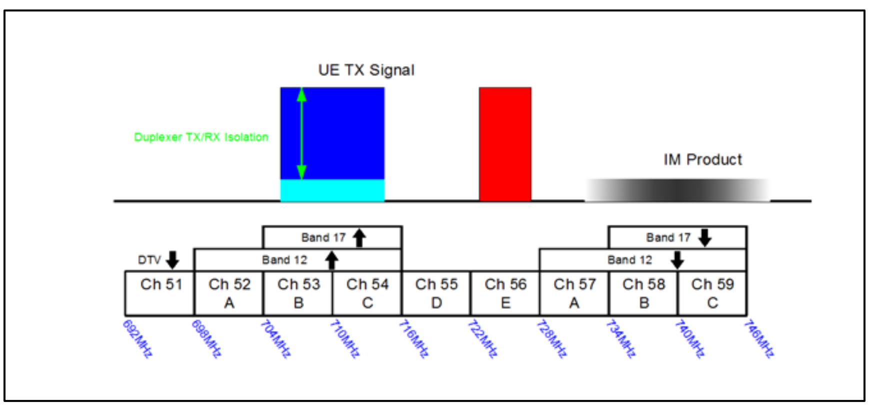


Figure 10 illustrates intermodulation interference in a consumer device with a 10 MHz wide transmission in the B and C Block. Carriers may choose this arrangement if they seek to

21 The actual intermodulation and reverse intermodulation products exceed the mathematical estimation (typically using the convolution operation) due to the non-ideal linearity of real devices and the large peak-to-average ratio of the signal of concern.

offer a broader bandwidth (and thus faster data-transfer speeds) to their subscribers and have licenses, or otherwise hold rights, to both the B and C Block in a location. Here the device's 10 MHz transmit signal (shown in blue) and the 6 MHz wide E Block signal (shown in red) lead to an intermodulation product (shown in black) that is centered between the B and C Blocks, and that spreads across and interferes with the device's desired signal in the B and C Block receive bands.

Manufacturers regularly use simulation tools to predict intermodulation power levels in order to ensure that they build devices that minimize intermodulation interference. For present purposes, Qualcomm used its standard simulation tool (*i.e.*, the simulation tool it regularly relies on to assess the performance of its own chipsets) to analyze the intermodulation products that would exist in a consumer device's receiver operating in the vicinity of a high-power E Block transmitter, assuming the receiver utilizes either a Band 12 or Band 17 filter. This tool simulates the intermodulation product, and then applies a channel filter to demonstrate how that filter mitigates the interference. Qualcomm's analysis used 5 MHz channels.

Using this information, Qualcomm's analysis found that consumer devices with a Band 12 filter would suffer harmful intermodulation interference. This analysis assumed that the device would transmit at 23 dBm, that the device would be capable of 55 dB of transmit/receive isolation, that the Band 12 filter would provide 7 dB of E Block rejection, and that the Band 17 filter would provide 49 dB of E Block rejection.[22] As seen in Table 4, Qualcomm's intermodulation analysis tool then was used to calculate the power of the intermodulation

[22] As discussed on pages 8-9, Qualcomm derived filter performance from performance specifications for currently available filters offered by first-tier manufacturers, namely Taiyo Yuden and Epcos.

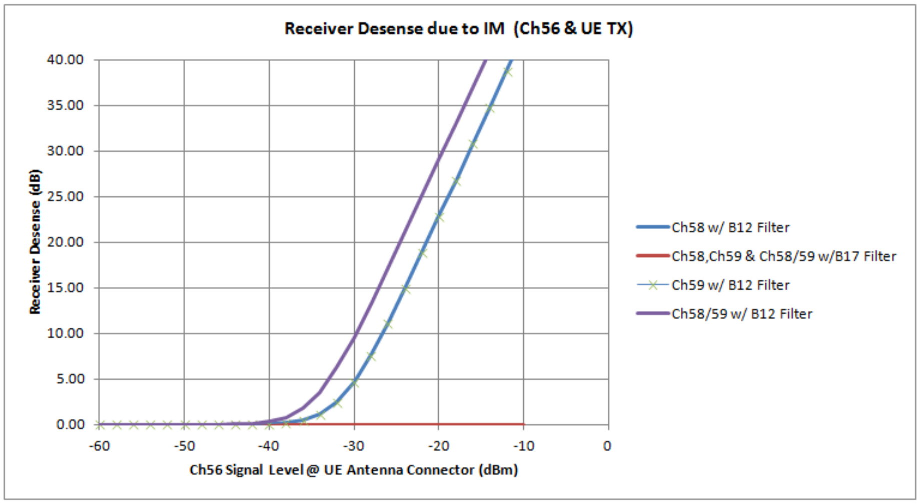
product for different E Block power levels at the device's antenna port, for situations where the carrier is operating only on the B Block, only on the C Block, and on both the B and C Block.

<u>Table 4</u>

Ch 56 Level @ UE Antenna Port (dBm)	Band 12 Duplexer				Band 17 Duplexer			
	Level after filter (dBm)	Ch58 Desense (dB)	Ch59 Desense (dB)	Ch58/59 Desense (dB)	Level after filter (dBm)	Ch58 Desense (dB)	Ch59 Desense (dB)	Ch58/59 Desense (dB)
-20	-27	22.9	22.8	29.1	-69	0.0	0.0	0.0
-30	-37	4.7	4.6	9.6	-79	0.0	0.0	0.0
-40	-47	0.1	0.1	0.3	-89	0.0	0.0	0.0
-50	-57	0.0	0.0	0.0	-99	0.0	0.0	0.0

Figure 11 illustrates these results with more specificity, and compares them to the success of the Band 17 filter in managing intermodulation interference. In locations where a device operating on either the B or C Block experiences an E Block power of -31.4 dBm or greater, it will experience, for example, desensitization of 3 dB or greater due to harmful intermodulation interference. E Block power of -29 dBm will generate 6 dB of desensitization for such a device, doubling the amount of interference. Where a device operating on both the B and C Block experiences E Block power of -34.5 dBm or greater, it will experience desensitization of at least 3 dB due to intermodulation interference. E Block power of -32.1 dBm will generate 6 dB or greater of desensitization.

Figure 11



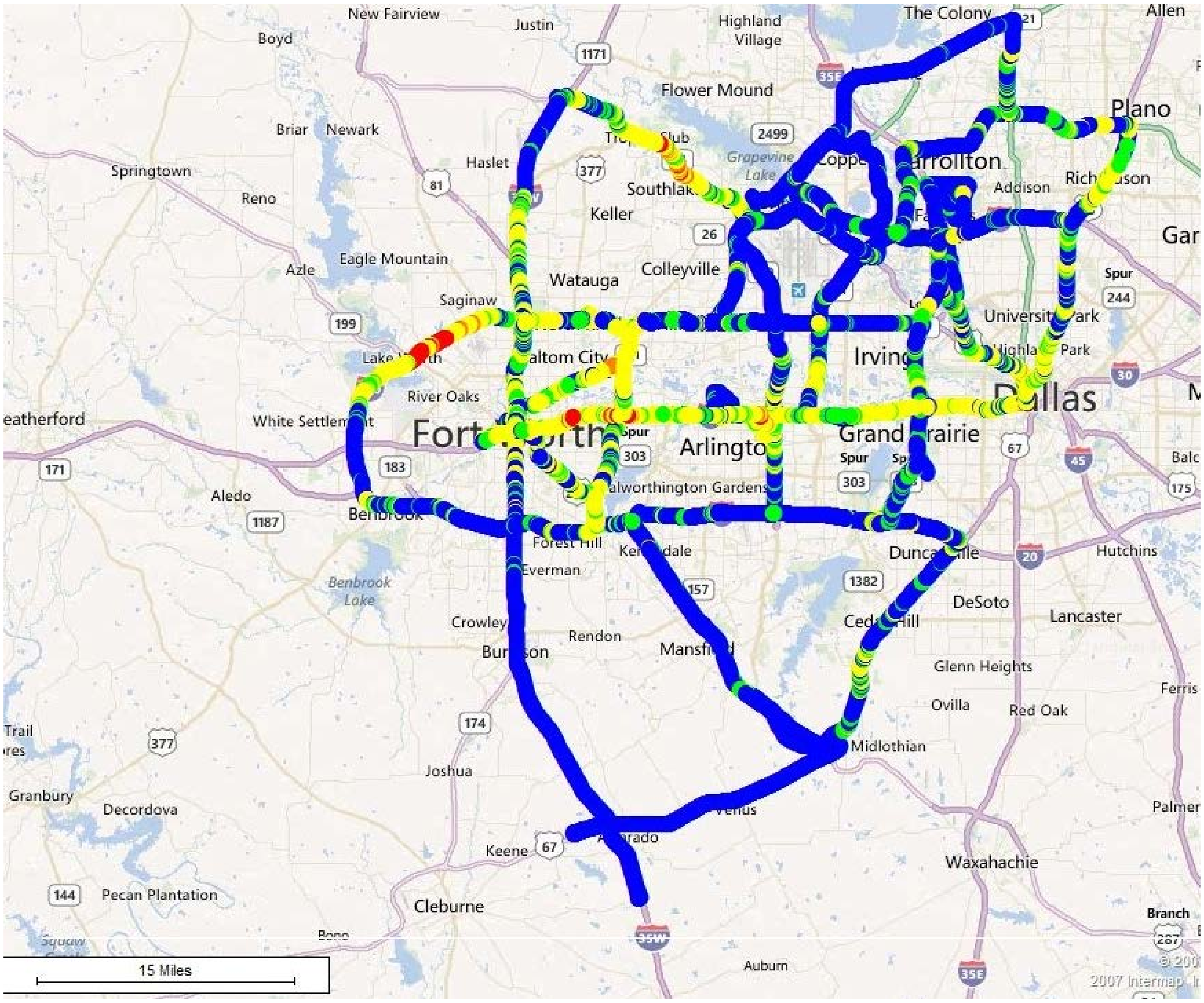
It is important to recognize that the blocking and intermodulation interference described above are cumulative. As a result, receivers suffer both jamming and intermodulation interference in many areas. With this in mind, the four maps that follow show the received power levels in the Dallas and Phoenix markets.

- Figures 12 (for Dallas) and 13 (for Phoenix) show the impact of blocking and intermodulation when a receiver expects a 5 MHz wide signal on the B Block (Channel 58).

- Figures 14 (for Dallas) and 15 (for Phoenix) show the impact of blocking and intermodulation when a receiver expects a 10 MHz wide signal on the B and C Blocks (Channels 58 and 59).

Areas shown in green and yellow would experience blocking interference. Areas shown in orange and red would experience blocking *and* intermodulation interference—resulting in even more substantial receiver desensitization, performance degradation, and capacity loss.

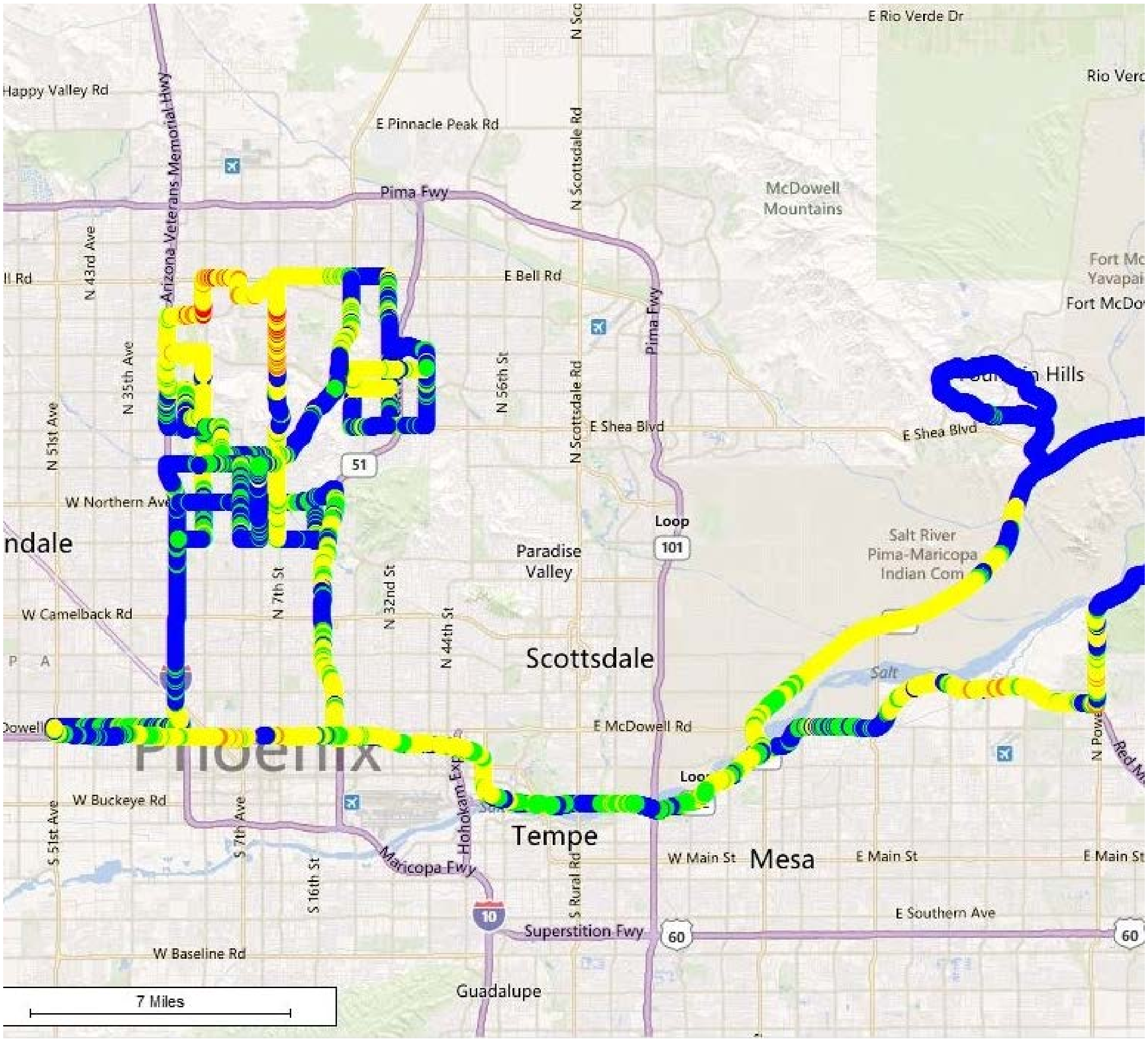
Figure 12
Blocking + Intermodulation Impact on Receiver Expecting a 5 MHz-Wide Signal
Dallas, TX[23]



Red: Above -29.1 dBm (Blocking and Intermodulation Interference)
Orange: -31.3 to 29.1 dBm (Blocking and Intermodulation Interference)
Yellow: -46.8 to 31.5 dBm (Blocking Interference)
Green: -51 to -46.8 dBm (Blocking Interference)
Blue: Below -51 dBm

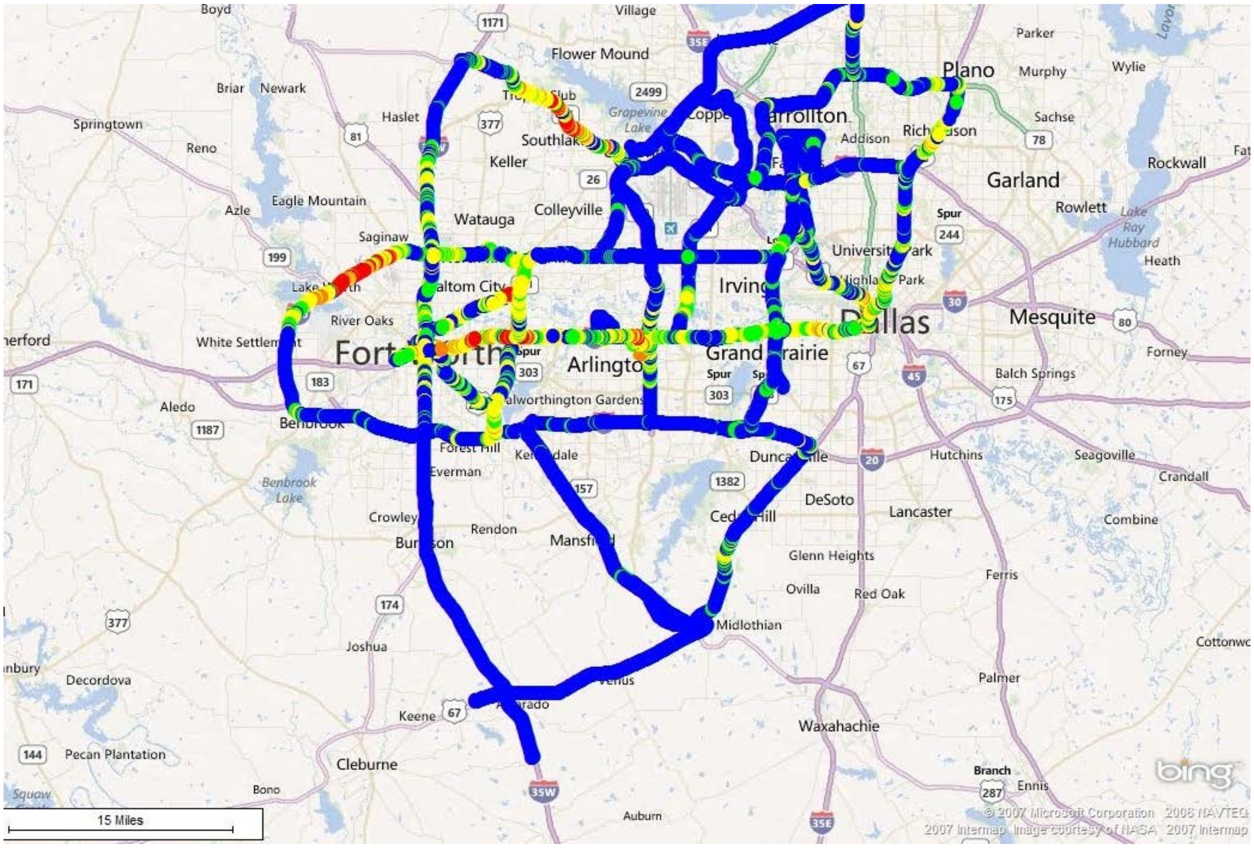
23 The maps do not illustrate cumulative desensitization. They show only where the E Block power levels are sufficiently high to independently cause blocking and intermodulation interference.

<u>Figure 13</u>
<u>Blocking + Intermodulation Impact on Receiver Expecting a 5 MHz-Wide Signal</u>
<u>Phoenix, AZ</u>



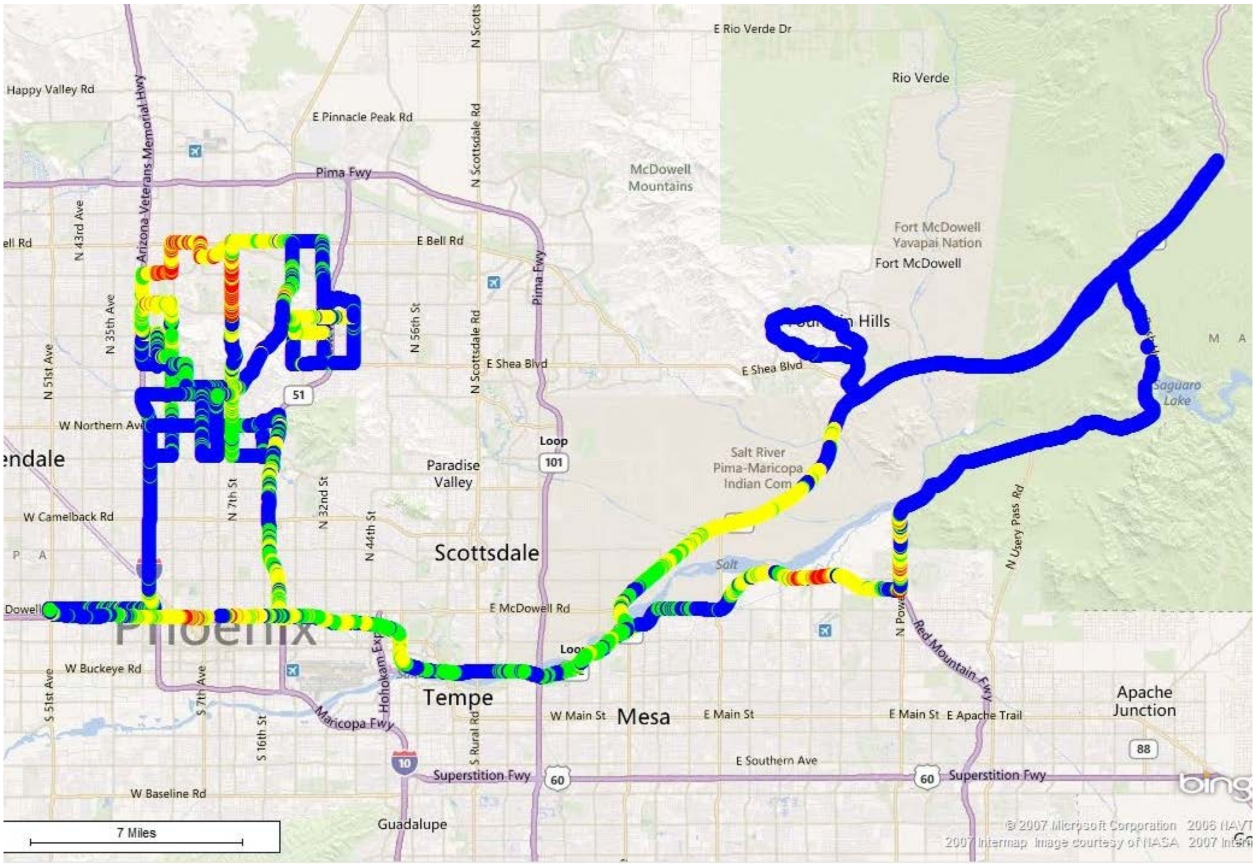
Red: Above -29.1 dBm (Blocking and Intermodulation Interference)
Orange: -31.3 to 29.1 dBm (Blocking and Intermodulation Interference)
Yellow: -46.8 to 31.5 dBm (Blocking Interference)
Green: -51 to -46.8 dBm (Blocking Interference)
Blue: Below -51 dBm

Figure 14
Blocking + Intermodulation Impact on Receiver Expecting a 10 MHz-Wide Signal
Dallas, TX



Red: Above -32.1 dBm (Blocking and Intermodulation Interference)
Orange: -34.5 to -32.1 dBm (Blocking and Intermodulation Interference)
Yellow: -44 to -34.5 dBm (Blocking Interference)
Green: -48.5-44 dBm (Blocking Interference)
Blue: Below -48.5 dBm

<u>Figure 15</u>
<u>Blocking + Intermodulation Impact on Receiver Expecting a 10 MHz-Wide Signal</u>
<u>Phoenix, AZ</u>



Red: Above -32.1 dBm (Blocking and Intermodulation Interference) **Orange: -34.5 to -32.1 dBm (Blocking and Intermodulation Interference)** **Yellow: -44 to -34.5 dBm (Blocking Interference)** **Green: -48.5-44 dBm (Blocking Interference)** **Blue: Below -48.5 dBm**

In sum, Qualcomm's analysis reveals that consumers across the country could encounter E Block power levels that are high enough to cause harmful interference from blocking and/or intermodulation to devices trying to transmit and receive on the Lower B and C Blocks using Band 12 filters.

C. Interference Mitigation Strategies and Field Tests Discussed in the NPRM.

The NPRM seeks comment on a mitigation technique and a study related to E Block interference. Specifically, the Commission asks whether:

- "[N]etwork operators can eliminate potential interference from Lower E Block operations by deploying the A, B, or C Block base stations near the E Block transmitters";[24]
- Field tests performed in Atlanta show that "the highest signal power ratios between the 50 kW Lower E Block and B Block are typically 15 to 30 dB lower than necessary to produce Lower B Block receiver blocking";[25] and
- "[T]est results confirm Band Class 12 performance would not be worse than Band Class 17 devices, and that Band Class 17 already has greater levels of internal interference from within the Lower B and C Blocks."[26]

Unfortunately, each of these claims is incorrect.

1. Base-Station Collocation Will Not Reduce Interference Caused by High-Power E Block Signals.

In some situations, operators of two different radio systems can effectively manage interference by collocating their base stations.[27] But this strategy only reliably controls

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[24] NPRM, ¶ 38.

[25] *Id*.

[26] *Id*.

[27] Dropped calls or degraded service can occur when a customer is far from any base station of his or her own system, but near a base station of a potentially interfering system. The desired signal is low (because it is attenuated by distance) but the potential interfering signal is at its strongest. This is therefore called the "near-far problem."

interference when the antenna patterns and coverage areas of the two radio systems are similar. For example, this strategy can successfully manage interference between cellular systems operating on adjacent channels because the two systems will have similar power limits and similar operational goals—meaning they are likely to have a similar number of base stations, and that each company will operate its base stations to achieve similar cell sizes—allowing the two companies to site their base stations in the same places, or where that is not possible, near one another.

Unfortunately, this collocation strategy will not work for Lower 700 MHz B and C Block licensees seeking to mitigate interference from the Lower 700 MHz E Block because the two systems are too dissimilar. FCC rules permit an E Block licensee to operate towers at 50,000 W—more than eight times the permitted power of a B or C Block base station in suburban and urban areas and more than four times the permitted power in rural areas.[28] Thus, under FCC rules, the E Block operators can use far fewer base stations to cover significantly larger cells than can B or C Block operators, and the antenna patterns of the two systems will be substantially different. For example:

- The average distance between cell sites in a typical cellular system is only 1.7 km or less, which is likely the appropriate distance for B and C Block cell sites. E Block operations will space towers much further apart, as Qualcomm did with its comparable MediaFLO system at Channel 55.

- B and C Block licensees likely will down-tilt antennas more than E Block antennas to reduce coverage areas and allow effective cellularization. E Block operators will take the opposite approach, engineering their towers to maximize coverage and achieve maximum received signal strength some distance away from their base stations, not immediately under base stations.

- B and C Block operators likely will spread base stations throughout their license areas. E Block operators again will take the opposite approach, locating towers

[28] *See* 47 C.F.R. §§ 27.50(c)(3)-(4).

> on mountaintops and other areas that allow maximum coverage for each tower, but that are usually inappropriate for cellular base stations.

Finally, many B and C Block licensees have already selected their antenna locations, deployed their networks, and are offering service.[29] But E Block service is not yet active and towers are not yet in place—making it unreasonable if not impossible for B and C Block licensees to collocate, even if such a strategy would otherwise be effective.

As a result, the FCC cannot rely on licensees using collocation to prevent blocking or intermodulation interference caused by E Block signals. At most, collocation would reduce interference in very localized areas, but this would not reduce total interference in a city or town or an overall region, leaving consumers unacceptably vulnerable to service outage, service degradation, and loss of capacity.

2. Vulcan Wireless' Field Test Is Not Reliable.

In order to better understand the potential for E Block operations to cause blocking interference to B and C Block consumer devices, Vulcan conducted field tests on a four-transmitter E Block test system located in Atlanta.[30] Vulcan likely chose this location for its test because, in the absence of a full nationwide deployment of E Block infrastructure by DISH, Atlanta was the only available test location. Vulcan reported that its test found that "the highest signal power ratios between the 50 kW Lower E Block and B Block are typically 15 to 30 dB lower than necessary to produce Lower B Block receiver blocking."[31] The report concludes that as a result, interference from E Block transmitters is manageable for Band Class 12 devices, and

[29] *See, e.g.*, Comments of AT&T Inc. at 10, RM-11592 (filed Mar. 31, 2010).

[30] Vulcan Study at 1. *See also* Vulcan Study, Attachment, Study to Review Interference Claims that have Thwarted Interoperability in the 700 MHz Band.

[31] NPRM, ¶ 38.

that the Band Class 17 filter is not necessary for Lower B and C block licensees to avoid harmful interference.

While Qualcomm appreciates the difficulty of testing E Block interference prior to roll out of service by DISH, Qualcomm has identified several flaws in the Vulcan test. First, because Vulcan did not have a location to test other than Atlanta, it was forced to study an inappropriate scenario.[32] The layout of the mini-E block test system tested in Atlanta does not represent either a worst-case scenario (which should be tested when analyzing interference) or a real-world scenario. This is the case because the Atlanta E block mini-deployment Vulcan studied was a test system with fewer transmitters and not intended to support commercial service. By contrast, Qualcomm presents measurements from its commercial deployment on Channel 55 in these comments, as described above. The Commission should therefore use Qualcomm's actual commercial measurements in its analysis, not those submitted by Vulcan.

Finally, the fact that Vulcan chose the Atlanta mini-deployment to study means that the relationship between the layout of the particular B block deployment in Atlanta and the Atlanta mini-test E block system reflected in its results is unlikely to be representative of what consumers will face across the country. The relative locations of Atlanta's B block base stations and mini-E block transmitters studied by Vulcan were mere happenstance. The Commission cannot determine, therefore, where E block transmitters would be located if the E block operator were operating a commercial service or how these locations would compare to the B block

[32] *See* Vulcan Study at 1, Attachment at 1. *Cf. Ex Parte* Letter of R. Paul Margie, Counsel to Qualcomm Inc., to Marlene H. Dortch, at 2, WT Docket No. 11-18 (filed Dec. 6, 2011) ("December 6, 2011 Qualcomm Ex Parte").

transmitters.[33] Conversely, the MediaFLO network was designed and validated by measurement for commercial service.

3. Interference Between B and C Block Operators Using the Band 17 Filter Would Not Lead To More Interference Than E Block Signals Would Cause to Operators Using the Band 17 Filter.

Finally, the NPRM asks if the Band 17 filter is not needed because the interference between B and C Block operators would cause more interference than E Block operations would cause to B and C Block devices.[34] This is incorrect.

B and C Block operators are able to mitigate interference to one another through the base-station collocation strategy described above. This strategy is successful because, in this case, B and C Block base stations have similar power levels and coverage areas. They also have a common 3GPP specification that governs blocking levels.[35] B and C Block operators will succeed in addressing the near-far problem using the same collocation strategy that other CMRS operators have used in many bands all across the country.

By contrast, B and C Block operators will not be able to collocate their base stations with 50,000 Watt E Block towers, which seek to cover huge geographic areas and likely will occupy locations that are inappropriate for cellular antennas. Additionally, B and C Block base stations are, in many areas, already deployed, while E Block operators have yet to build out their

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33 It also appears that Vulcan may have tested devices equipped with the Band 17 filter. If this is true, the test results would show that the Band 17 filter's superior rejection of E Block signals produced the power ratios found by Vulcan. If Vulcan did in fact use the Band 17 filter, this suggests that if testing devices were equipped with a Band 12 filter, the ratio likely would have been worse—possibly 40 dB worse—enough to produce the harmful blocking and intermodulation interference to the B and C block discussed above.

34 NPRM, ¶¶ 40, 43. *See also* Vulcan Study at 2, Attachment at 5; *see also Ex Parte* Letter of Michele C. Farquhar, Counsel to Vulcan Wireless LLC, to Marlene H. Dortch, FCC, at 2, WT Docket No. 11-18 (filed Dec. 6, 2011).

35 *See, e.g.*, 3GPP TS 36.101, ¶¶ 7.6.1, 7.6.2.

networks, making collocation impossible. These two interference scenarios are fundamentally different.

III. EFFECTS OF CHANNEL 51 DIGITAL TELEVISION SIGNALS ON CONSUMER DEVICES SEEKING TO RECEIVE B AND C BLOCK SIGNALS.

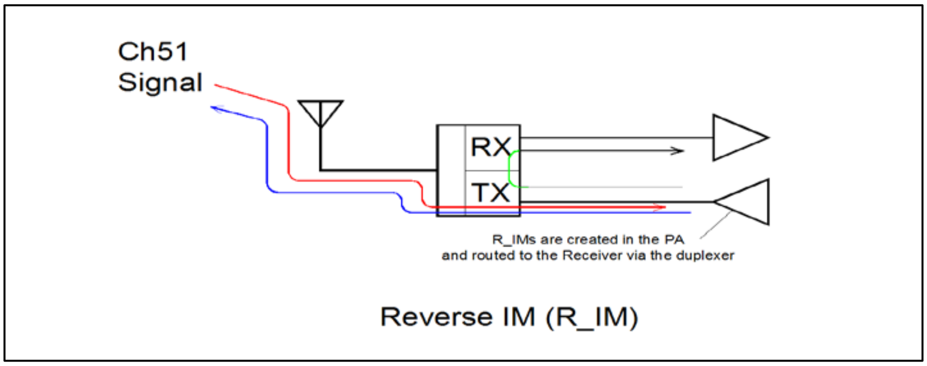
Qualcomm has also examined the potential interference issues caused by broadcast signals on Channel 51. This testing indicates that signals from Channel 51 could cause harmful reverse intermodulation interference, in situations discussed below, to consumer devices seeking to receive on the B and C Blocks without a filter that sufficiently attenuates Channel 51 at the devices' transmission (output) channel.[36] Qualcomm's study of the issue shows that while a Band 17 filter successfully protects against this reverse intermodulation interference, a Band 12 filter does not. Qualcomm's analysis of the issue further shows that proposed mitigation measures, including coordination between Channel 51 and Lower 700 MHz licensees, are insufficient to address this interference.

Reverse intermodulation interference occurs when a signal from high-powered operations on a nearby channel (represented by the red line in Figure 16 below) is received by the antenna of a device operating on a nearby channel, and then enters the output port of the device's power amplifier (hence, "reverse" intermodulation). Here the signal mixes with the device's transmit signal (the blue line) entering through the input port. This mixing creates an intermodulation product (the grey line) that falls on the Lower B and C Blocks' receive frequencies. After being attenuated by the device's transmission/receive isolation function (the green line), it enters the device's receiver and can lead to desensitization (the black line). Sufficient rejection of the aggressor signal from the adjacent channel *before* that signal enters the device's power amplifier

[36] *See* NPRM, ¶¶ 33-36, 40.

can mitigate reverse intermodulation interference. After the adjacent channel signal mixes with the in-band signal, the device's receiver will be unable to filter out the unwanted signal, as it falls squarely within the receiver's intended receive frequencies.

Figure 16



A. Qualcomm's Measurements of Channel 51 Reverse Intermodulation Interference Demonstrate a Risk to Consumer Devices Absent Sufficient Filtering.

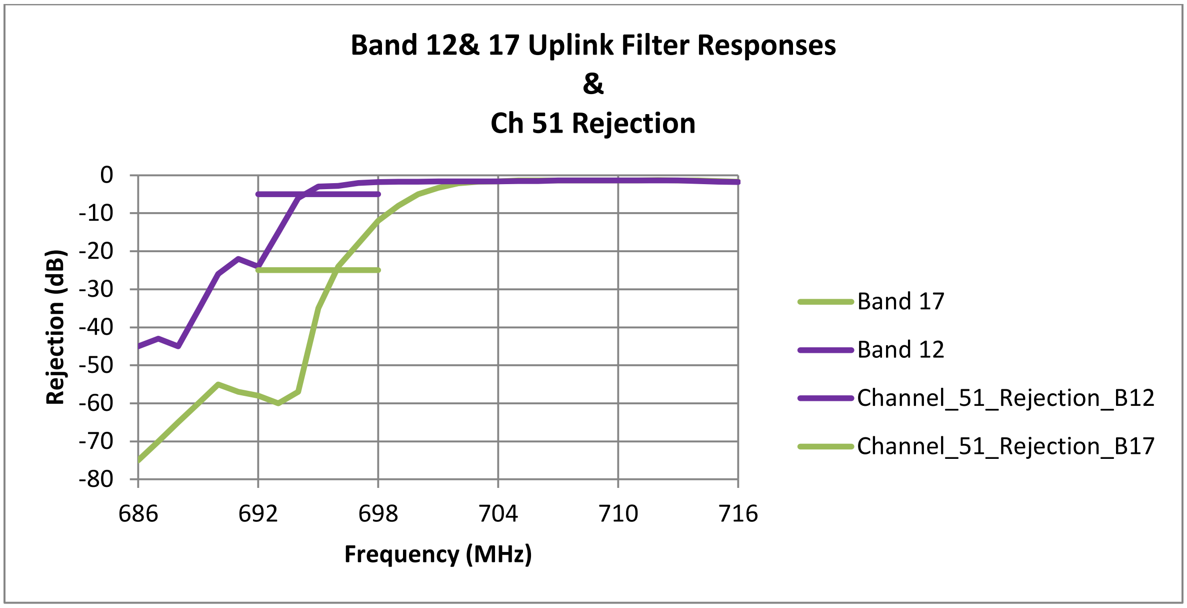
As with the other types of interference discussed above, device and component manufacturers use filters to mitigate the risk of reverse intermodulation interference. Therefore, as it did with E Block interference concerns, Qualcomm performed an analysis to study whether the Band 12 and/or Band 17 filters would adequately protect against reverse intermodulation interference due to Channel 51.

For its analysis, Qualcomm used the parameters of commercially available Band 12 and Band 17 filters from first-tier suppliers.[37] Figure 17 illustrates the ability of such Band 12 and Band 17 filters to reject Channel 51. As the figure shows, the Band 12 filter provides

[37] As previously noted, the commercially available Tier 1 filters that Qualcomm considered were from Avago, Epcos, MuRata, Taiyo Yuden, and Triquint. Figure 17 is based on Epcos Band 12 and 17 filters.

approximately 5 dB of rejection of Channel 51, compared to approximately 25 dB of rejection of Channel 51 provided by the Band 17 filter.[38]

Figure 17



There are very few technical or scholarly studies providing empirical data on the measurement of reverse intermodulation, and no accepted formula for predicting it.[39] Qualcomm accordingly made actual measurements of reverse intermodulation in lab tests designed to measure device performance in a number of different conditions.

Qualcomm measured the impact of Channel 51 DTV transmissions on a device attempting to receive LTE transmissions on the B Block (5 MHz bandwidth), on the C Block (5

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38 As with the attenuation of Channel 56, the Band 17 filter is able to use a 6 MHz guard band because it need not provide attenuation of Channel 51 over Channel 52. By starting its attenuation at Channel 53, the Band 17 filter is able to provide far greater attenuation of the Channel 51 signal. It is this wide disparity in rejection of the Channel 51 signal that would cause Lower B and C Block operators to suffer harmful interference from reverse intermodulation from the Channel 51 signal, if they are required to use Band 12 filters in their commercial devices.

39 *See, e.g.*, Allen Katz *et al.*, *Sensitivity and Mitigation of Reverse IMD in Power Amplifiers* at 53 (2011 IEEE Topical Conference on Power Amplifiers for Wireless & Radio Applications (PAWR), No. 10.1109/PAWR.2011.5725374 (2011)).

MHz bandwidth), and on both the B and C Blocks (10 MHz bandwidth). Qualcomm's testing shows that the problem of reverse intermodulation arises particularly in the latter two cases—devices attempting to send and receive LTE transmissions on the C Block (5 MHz bandwidth) and on the B and C Blocks (10 MHz bandwidth).[40] The section below therefore focuses on the results of those measurements.

Qualcomm conducted its measurements using a commercially-available power amplifier and examined the results for three gain states, collecting data for the upper and lower ends of each gain state. These gain states correspond to the power levels used by user equipment (cell phones, tablets, laptops, etc.). High gain corresponds to high or full power transmission; mid gain corresponds to medium power transmission; and low gain corresponds to low power transmission. Device manufacturers use these gain states to extend battery life and maximize device performance.

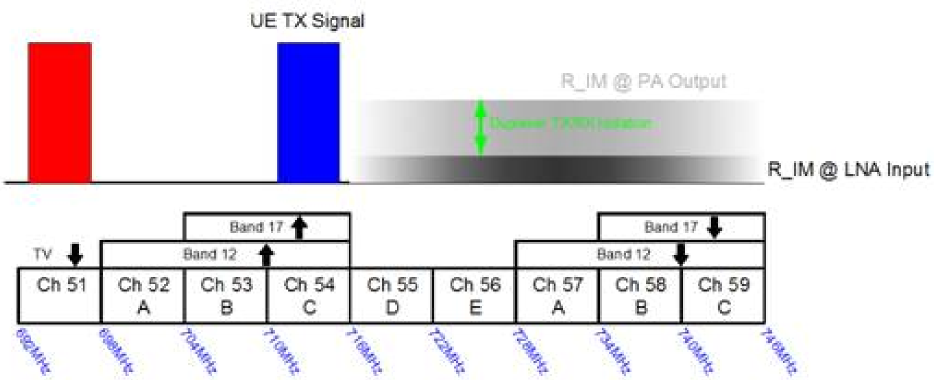
The measurements verify the existence and extent of the reverse intermodulation that will be experienced when devices using a Band 12 or Band 17 filter attempt to transmit within 24 MHz of a Channel 51 DTV station.

[40] Intermodulation and reverse intermodulation are not frequency dependent. This is because intermodulation expresses a relationship between amplitude and relative frequency and does not need to depend on absolute frequency. The Vulcan study provided the FCC with no frequency measurements, most likely for this reason. Due to the lack of dependence on absolute frequency, Qualcomm performed its measurements on equipment available to it at the time of the tests, using a Band 1 power amplifier with three gain modes, operating within 24 MHz of a DTV transmission. For the TV signal, Qualcomm used DTV waveform at 1954 MHz. For the user equipment transmission, Qualcomm used UMTS waveform at 1930 MHz. Qualcomm a Triquint TQM776011 UE power amplifier with 3 gain modes. It appropriately assumed a receiver noise figure of 6 dB, and a receiver filter capable of providing 60 dB of transmit/receive isolation at the receiver channel.

1. Reverse Intermodulation Between Channel 51 and a 5 MHz bandwidth LTE C Block Uplink Signal.

Figure 18 illustrates a situation where a consumer device is operating on the C Block in the face of Channel 51. In terms of relative power levels, the device's 5-MHz wide transmit signal in blue and the 6-MHz wide Channel 51 signal in red combine to create an intermodulation product (shown in black) centered on the A Block, but that product spreads and interferes with the device's B and C Blocks as well.

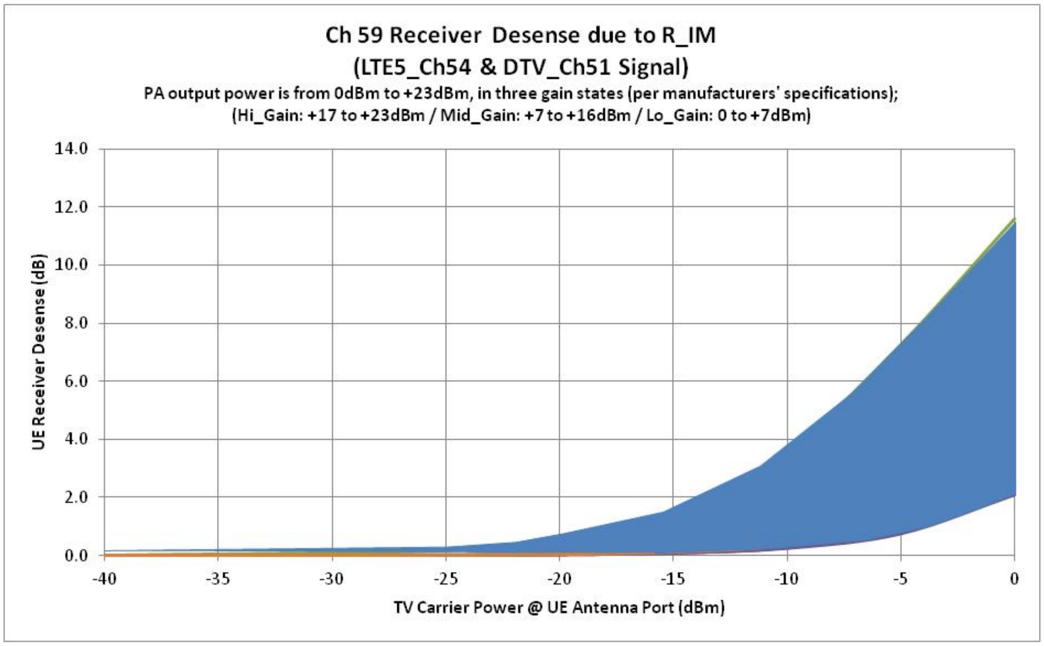
<u>Figure 18</u>



As described above, because there is no accepted model for predicting reverse intermodulation powers, Qualcomm performed lab measurements to test this scenario. It measured equipment in high-, mid-, and low-gain states, taking measurements at both the high and low end of the gain state ranges.

As shown in Figure 19, Qualcomm's tests revealed that a device attempting to send and receive C Block signals (5 MHz bandwidth) in the presence of a Channel 51 signal will begin to experience desensitization when the Channel 51 signal at the device measures -20 dBm or stronger. To avoid such desensitization, therefore, the device would have to be equipped with a filter that would suppress Channel 51 signals to below the -20 dBm level.

<u>Figure 19[41]</u>



The blue area represents the range of desensitization experienced in different gain state/power level situations.

For example, as shown in Figure 19, at a received (unfiltered) Channel 51 signal of -10 dBm, a mobile device filter would need to provide at least 10 dB of rejection, such that the actual received Channel 51 signal in the device's output channel would be at or lower than -20 dBm, in order to avoid interference. A Band 17 filter will have no difficulty achieving this level of

41 As discussed in Section III.B.1 below, mobile devices transmit over a range of output levels, and switch gain states to conserve energy. Reverse intermodulation interference varies depending on the particular gain state and power level of the device at each moment. Because a device can be at any combination of gain state and power level at any time, Figure 19's blue area shows the range of desensitization for a variety of gain states and power levels.

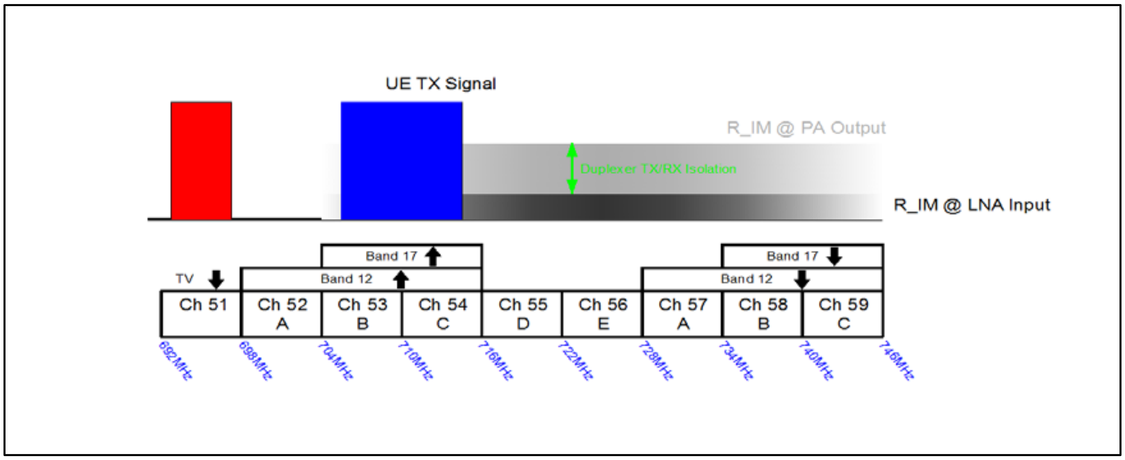
protection because it provides 25 dB of rejection. A Band 12 filter, however, provides only 5 dB of attenuation (see Figure 17), and thus will not prevent all interference where the Channel 51 signal is at -15 dBm or stronger. The filter will be close to its limits and device performance likely will start to degrade. Indeed, the degradation will begin when the Channel 51 signal is between -20 and -10 dBm.

In order to obtain a full picture of the interference risk, and as discussed more fully on pages 44-54 below, Qualcomm examined the potential Channel 51 signal levels in certain major markets where Channel 51 DTV stations operate. As shown there, Qualcomm's analysis suggests that a Channel 51 signal level of -10 dBm is expected in multiple locations in such markets. For example, the Channel 51 DTV station in Chicago is likely to produce a signal at an average received power level for user equipment of -10 dBm or more in an 8 square mile area in downtown Chicago. For devices seeking to transmit on Channel 54 and receive on Channel 59, that entire area will be at risk of harmful interference from reverse intermodulation. In fact, the area where the degradation will begin consists of a 94 square mile area covering much of the greater Chicago area, in which the Channel 51 received power level is predicted to be -20 dBm or greater. These results show potentially severe degradation to C Block licensees' service in Chicago, were the FCC to mandate use of a Band 12 filter for Block C licensees.

2. Reverse Intermodulation between Channel 51 and a 10 MHz bandwidth LTE B and C Block Uplink Signal.

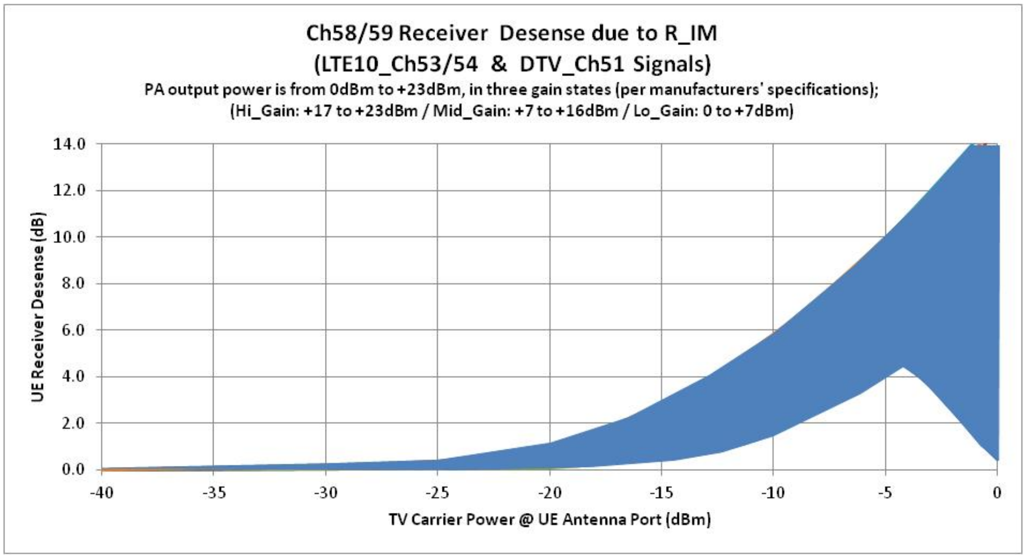
Qualcomm also calculated the extent of the reverse intermodulation for a consumer device attempting to transmit and receive LTE signals (10 MHz bandwidth) on the B and C Blocks in the presence of a strong Channel 51 signal. As shown in Figure 20, the resulting reverse intermodulation product will land on the A, B, and C Blocks.

Figure 20



Qualcomm's lab measurements found that the harm from reverse intermodulation in this scenario is more severe than when a device utilizes only the C Block. Reverse intermodulation presents noticeable desensitization when Channel 51 received signal strength is approximately -20 dBm or stronger, and can reach 6 dB of desensitization at a Channel 51 received signal of -10 dBm, as shown in Figure 21 below.

Figure 21[42]



The blue area represents the range of desensitization experienced in different gain state/power level situations.

Here, Qualcomm's test data show that a mobile device operating in the presence of a -10 dBm Channel 51 signal would have to be able to provide at least 15 dB of rejection to avoid harmful interference. A Band 17 device will do so and still have ample margin to accommodate any other interference. A Band 12 device will be overloaded by the reverse intermodulation alone.

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42 As discussed in Section III.B.1 below, mobile devices transmit over a range of output levels, and switch gain states to conserve energy. Reverse intermodulation interference varies depending on the particular gain state and power level of the device at each moment. Because a device can be at any combination of gain state and power level at any time, Figure 21's blue area shows the range of desensitization for a variety of gain states and power levels.

3. Without a Band 17 Filter, Reverse Intermodulation Interference Would Create De Facto Exclusion Zones for Customers of B and C Block Licensees.

As a result of the reverse intermodulation described above, consumer device performance will begin to degrade in areas where the filtered Channel 51 signal strength is -20 dBm or stronger. In this situation, operators will experience capacity degradation because devices operating at a distance from their base stations will demand additional network resources to overcome desensitization. In addition, cell sizes will begin to shrink and consumers will lose service in marginal areas like underground parking garages, elevators, building interiors, and at the edge of coverage. In areas where the received Channel 51 signal strength is higher, cell sizes will shrink further and mobile device performance will become increasingly degraded, especially indoors. The effect of this reverse intermodulation interference will be to create *de facto* exclusion zones near Channel 51 transmitters.

Qualcomm examined the likely real-world impact of reverse intermodulation interference in large metropolitan areas, using a three-part methodology. First, following the FCC's recommended approach, it predicted Channel 51 signal strength using the Longley-Rice method.[43] Qualcomm then input this data into the radio coverage prediction tool created by the Communications Research Centre of Canada[44] to predict Channel 51 signal strength in the area around the Channel 51 transmitter, and applied an offset to account for the difference in antenna gain between a TV antenna (as seen in the FCC method) and a mobile device. Accordingly, Qualcomm entered data such as the following into the CRC Radio Coverage Prediction Tool

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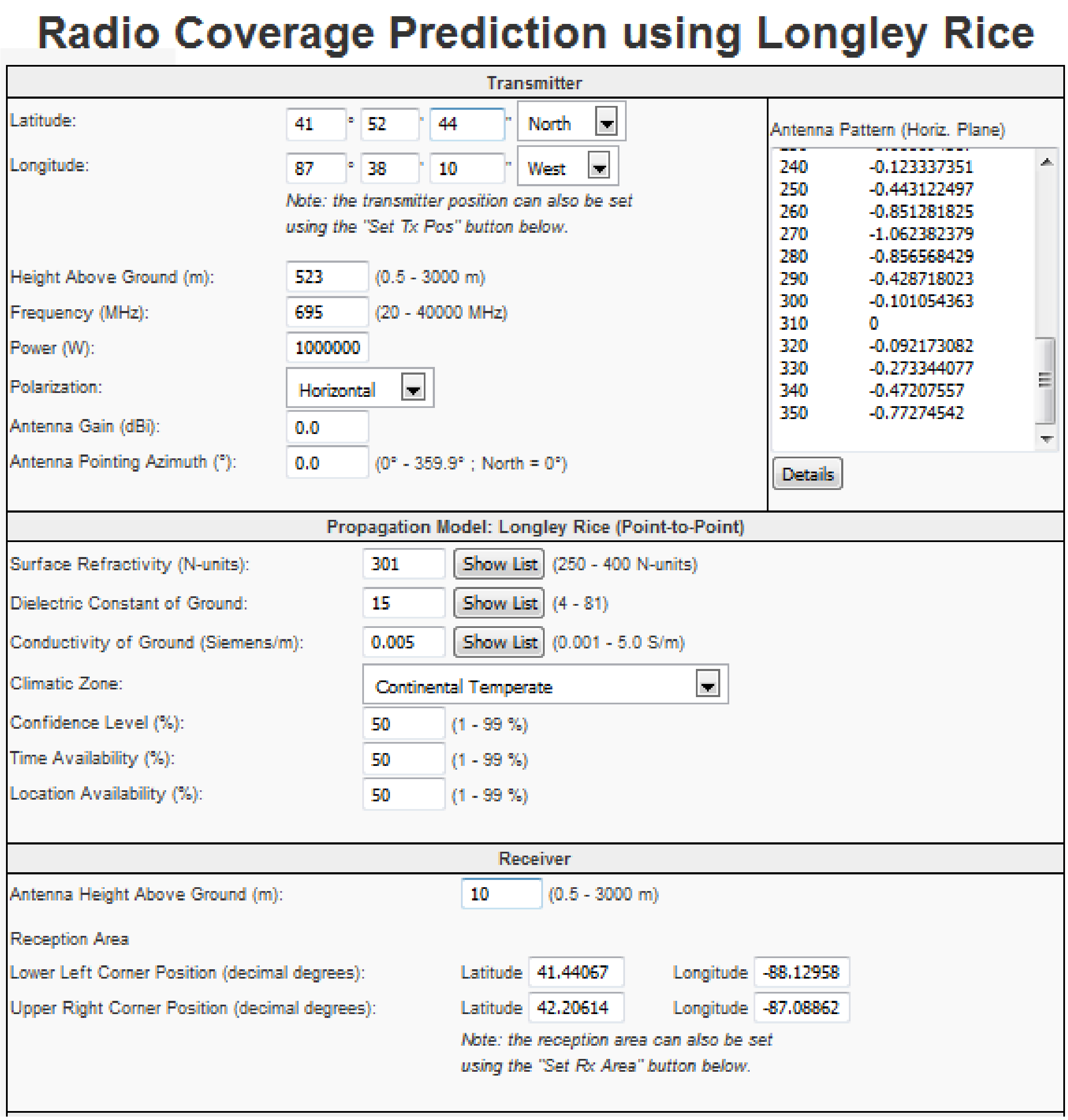
43 Office of Engineering and Technology, Bulletin No. 69, *Longley-Rice Methodology for Evaluating TV Coverage and Interference* (Feb. 6, 2004); *Qualcomm Inc. Petition for Declaratory Ruling*, Order, ¶ 1, WT Docket 05-7 (rel. Oct. 13, 2006).

44 *See* Communications Research Centre of Canada, CRC-COVLAB, http://www.crc.gc.ca/en/html/covlab/home/features/features/.

(Figure 23 is an example of Qualcomm's Longley-Rice input parameters—each location is unique, and the input parameters were taken from the FCC database for each station):

Figure 22



Radio Coverage Prediction using Longley Rice

Transmitter

Latitude:	41 ° 52 ' 44 " North
Longitude:	87 ° 38 ' 10 " West
	Note: the transmitter position can also be set using the "Set Tx Pos" button below.
Height Above Ground (m):	523 (0.5 - 3000 m)
Frequency (MHz):	695 (20 - 40000 MHz)
Power (W):	1000000
Polarization:	Horizontal
Antenna Gain (dBi):	0.0
Antenna Pointing Azimuth (°):	0.0 (0° - 359.9° ; North = 0°)

Antenna Pattern (Horiz. Plane)

240	-0.123337351
250	-0.443122497
260	-0.851281825
270	-1.062382379
280	-0.856568429
290	-0.428718023
300	-0.101054363
310	0
320	-0.092173082
330	-0.273344077
340	-0.47207557
350	-0.77274542

Details

Propagation Model: Longley Rice (Point-to-Point)

Surface Refractivity (N-units):	301 Show List (250 - 400 N-units)
Dielectric Constant of Ground:	15 Show List (4 - 81)
Conductivity of Ground (Siemens/m):	0.005 Show List (0.001 - 5.0 S/m)
Climatic Zone:	Continental Temperate
Confidence Level (%):	50 (1 - 99 %)
Time Availability (%):	50 (1 - 99 %)
Location Availability (%):	50 (1 - 99 %)

Receiver

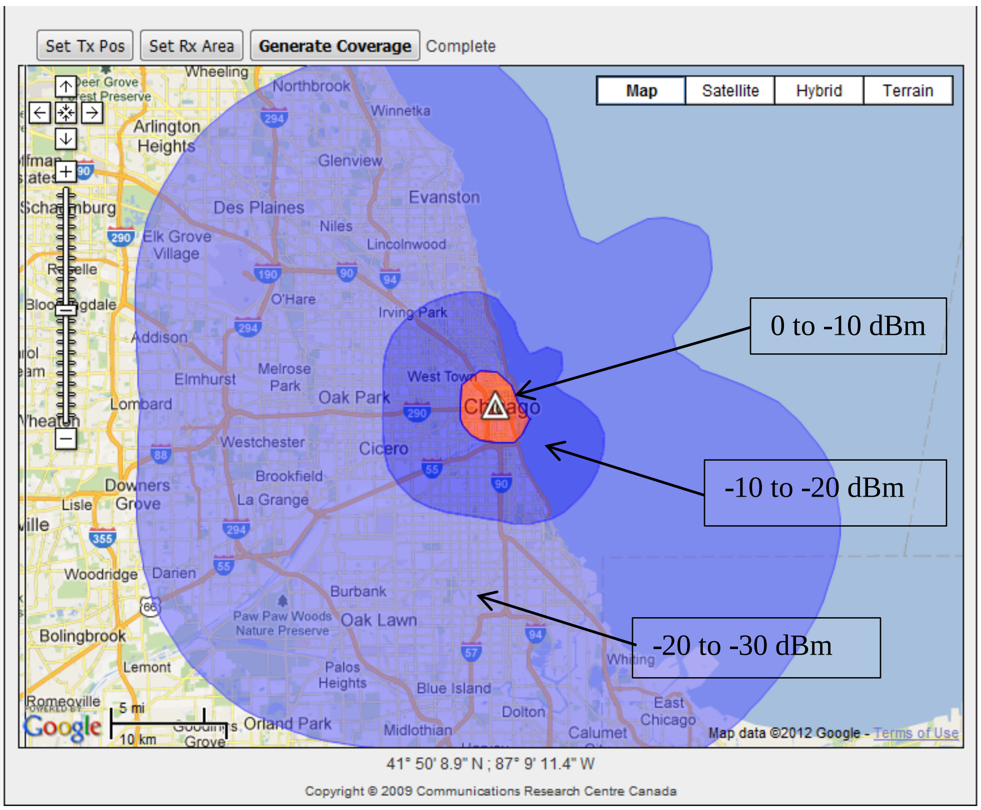
Antenna Height Above Ground (m):	10 (0.5 - 3000 m)
Reception Area	
Lower Left Corner Position (decimal degrees):	Latitude 41.44067 Longitude -88.12958
Upper Right Corner Position (decimal degrees):	Latitude 42.20614 Longitude -87.08862
	Note: the reception area can also be set using the "Set Rx Area" button below.

Finally, Qualcomm used the FCC's DTV Reception Maps tool available on the DTV.gov website to verify the predicted signal strength of the Channel 51 transmitters in each location.

For each of these maps, we show not only the areas of greatest concern, but also borderline areas where consumers will experience Channel 51 signal strengths of -20 to -30 dBm. Because these power levels are predictive of interference and substantial fluctuations will occur during actual operation, consumers may experience interference even in the borderline -20 to -30 dBm areas.

For an antenna positioned at a height of 1.5 meters, as would be typical for a handset, the FCC's preferred methodology predicts the following received Channel 51 signal in Chicago, IL (Figure 23):

Figure 23

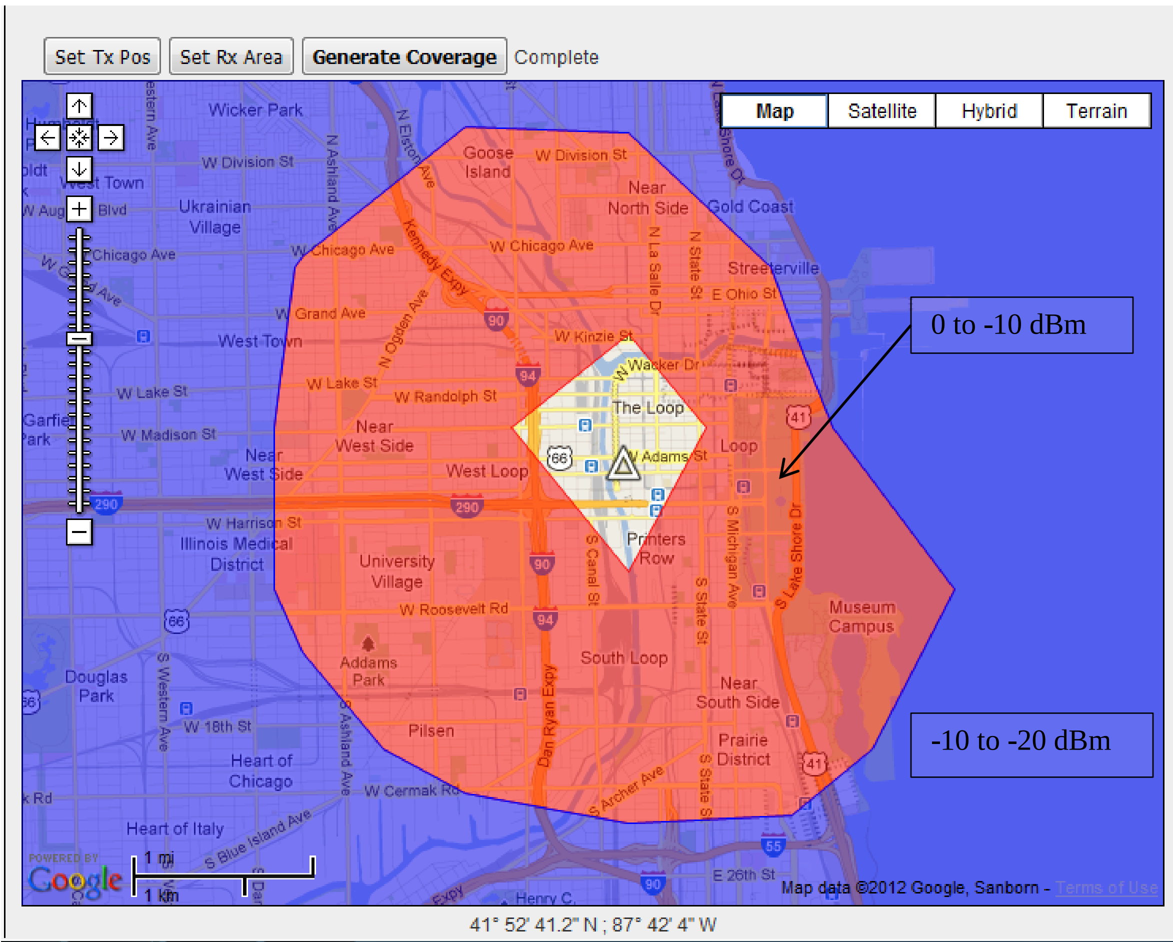


Red: -10 to 0 dBm
Dark Blue: -20 to -10 dBm
Light Blue: -30 to -20 dBm

As noted, the red inner circle (approximately 8 square miles) represents areas where the Channel 51 signal is predicted to be 0 to -10 dBm; the dark blue represents areas (approximately 94 square miles) where the Channel 51 signal is predicted to measure -10 to -20 dBm, and the light blue (approximately 1,200 square miles) represents predicted Channel 51 signals of -20 to -30 dBm.

Applying the analysis described above to the Channel 51 transmitter in Chicago, IL (WPWR), we find that the majority of Chicago's Loop and surrounding areas is predicted to suffer a coverage gap, and that much of the city, its principal interstate and highway arteries, and surrounding suburbs, would suffer degraded service or no service at all. Figure 24 provides a more detailed picture of the predicted impact of reverse intermodulation in central Chicago.

<u>Figure 24</u>[45]

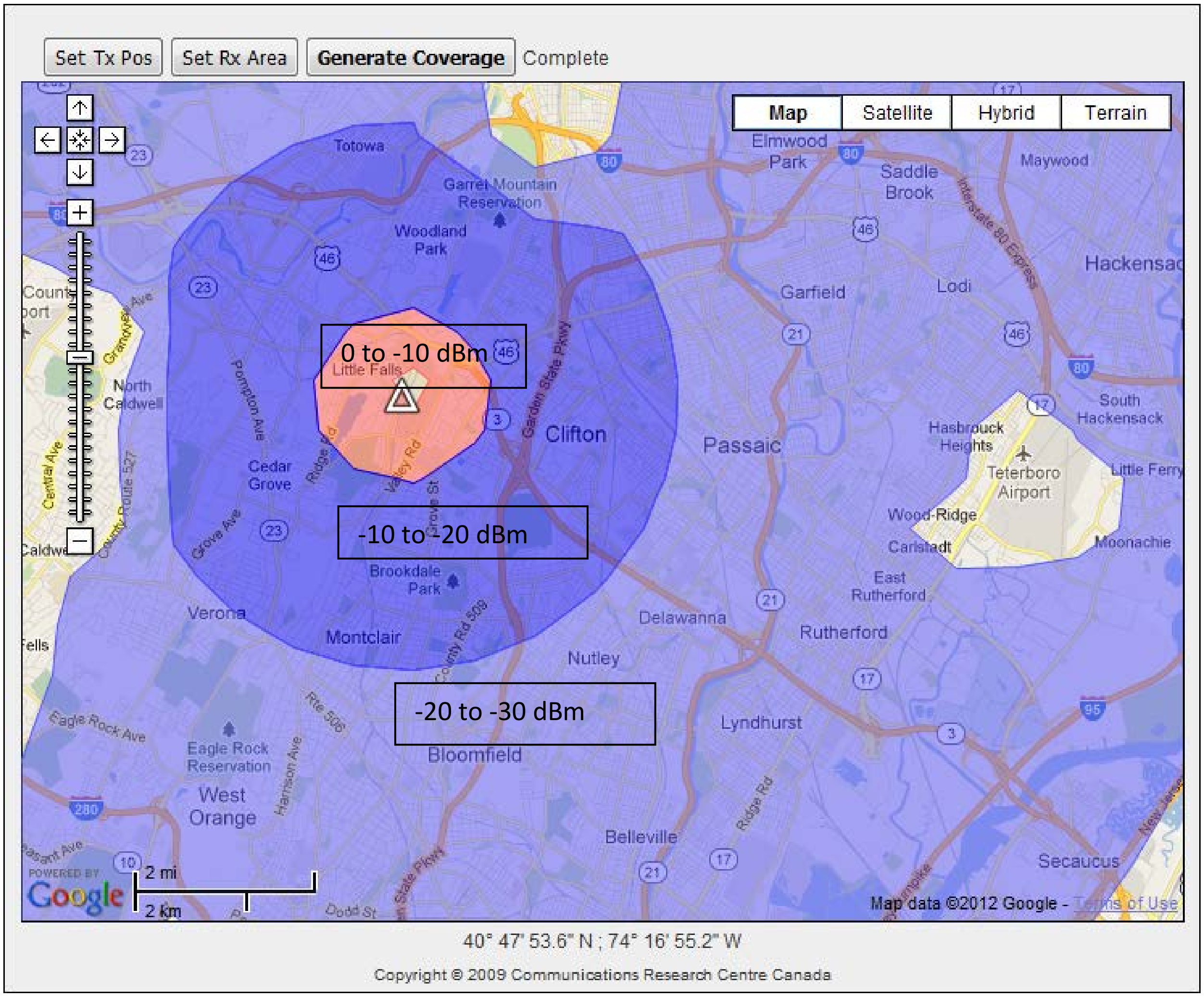


Red: -10 to 0 dBm
Dark Blue: -20 to -10 dBm

45 The uncolored areas immediately around the transmitter are areas where Channel 51 signal strength exceeds 0 dBm, but where the tool's predictive powers are not always reliable. To be conservative, Qualcomm focused on areas of predicted signal strength below 0 dBm.

Similarly, for an antenna at 1.5 meters, as would be typical for a handset, the FCC's preferred methodology predicts the following received Channel 51 signal in Montclair, NJ (Figure 25).

Figure 25



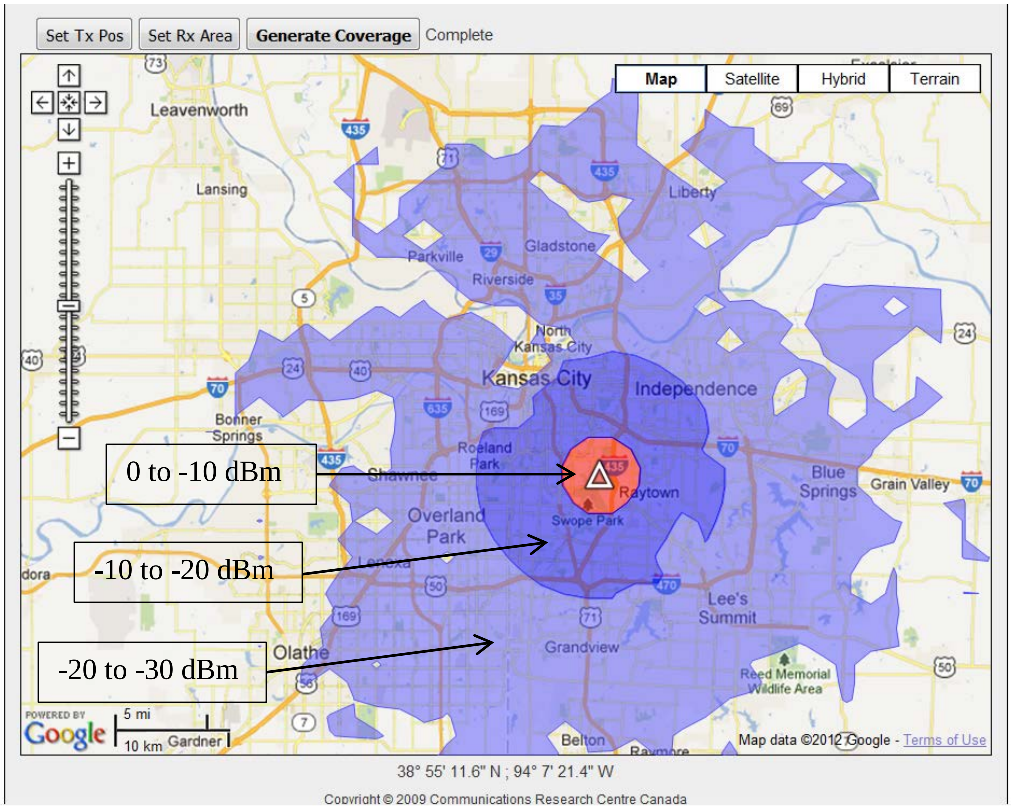
Red: -10 to 0 dBm
Dark Blue: -20 to -10 dBm
Light Blue: -30 to -20 dBm

The red inner circle (approximately 2.7 square miles) represents areas where the Channel 51 signal measures 0 to -10 dBm; the dark blue represents areas (approximately 30 square miles) where the Channel 51 signal measures -10 to -20 dBm, and the light blue (approximately 300 square miles) represents Channel 51 signals of -20 to -30 dBm.

Applying the analysis described above to the Channel 51 transmitter in Montclair, NJ, (WNJN), it is predicted that significant areas of heavily used commuter routes linking suburban New Jersey to and from New York City, including Routes 3 and 46, and the Garden State Parkway, may experience harmful reverse intermodulation interference if they are on the edge of coverage. Even limiting review to the area of clear interference – the red area adjacent to the Channel 51 transmitter where consumers will receive Channel 51 signals of between 0 and -10 dBm – reveals a populated 2.7 sq. mi. area where residents, businesses, and commuters will be likely to suffer a coverage gap. Adding the larger area where consumers may receive Channel 51 signal strengths of -10 to -20 dBm shows a huge potential zone where a vast number of consumers every day are predicted to experience degraded service.

Likewise, Qualcomm's examination predicts that the Channel 51 station in Kansas City will produce a signal of -10 dBm or greater in a 14 square mile area that includes a several mile stretch of I-435. And, this station is predicted to produce a signal of between -20 and -10 dBm in a 115 square mile area that includes large swaths of two interstate highways, I-70 and I-470, and the major roads immediately to the South of metropolitan Kansas City (Figure 26).

Figure 26

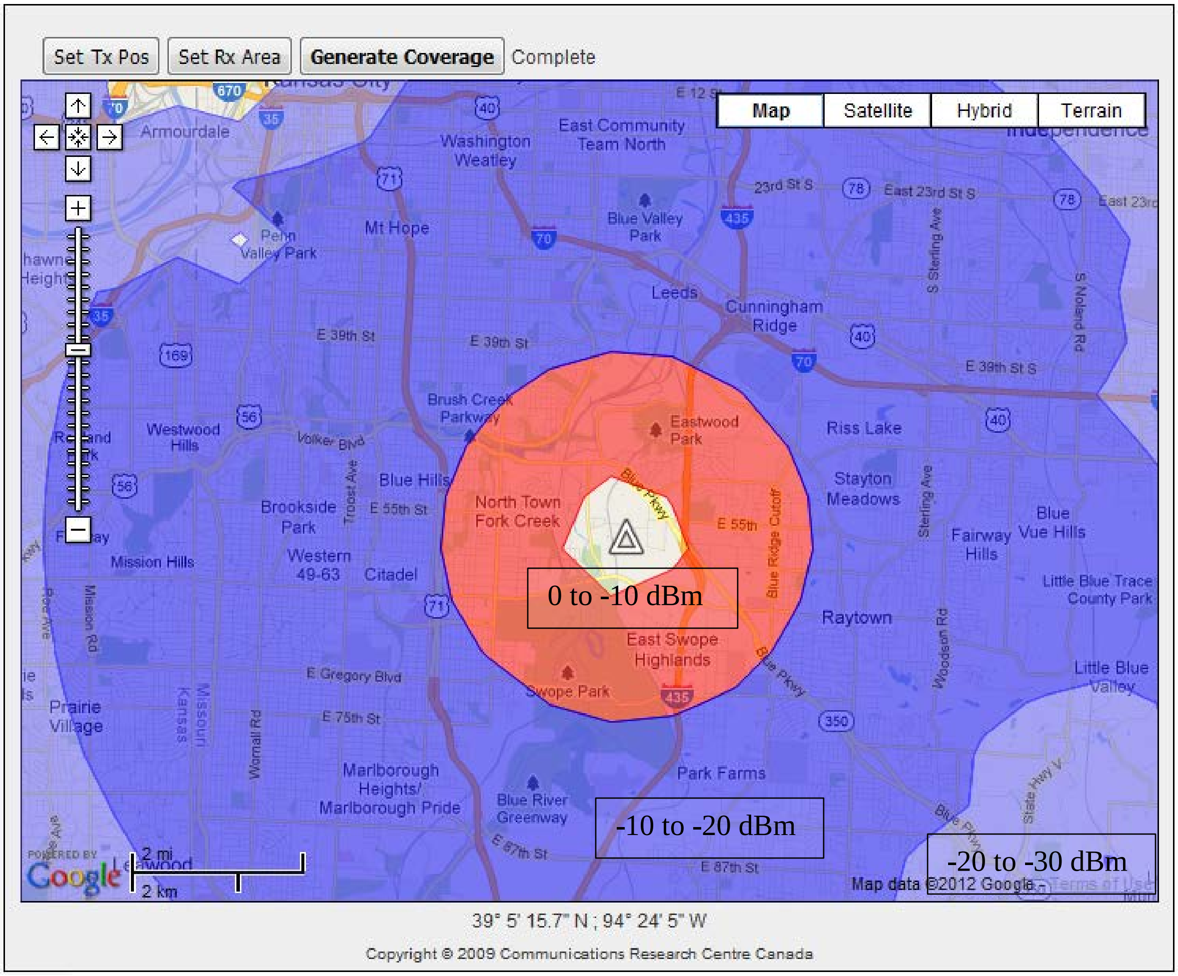


Red: -10 to 0 dBm
Dark Blue: -20 to -10 dBm
Light Blue: -30 to -20 dBm

The red inner circle (approximately 14 square miles) represents areas where the Channel 51 signal measures 0 to -10 dBm; the dark blue represents areas (approximately 115 square miles) where the Channel 51 signal measures -10 to -20 dBm, and the light blue (approximately 600 square miles) represents Channel 51 signals of -20 to -30 dBm.

Figure 27 provides a detailed view of the impact of reverse intermodulation interference on Kansas City.

<u>**Figure 27**</u>



Red: -10 to 0 dBm
Dark Blue: -20 to -10 dBm
Light Blue: -30 to -20 dBm

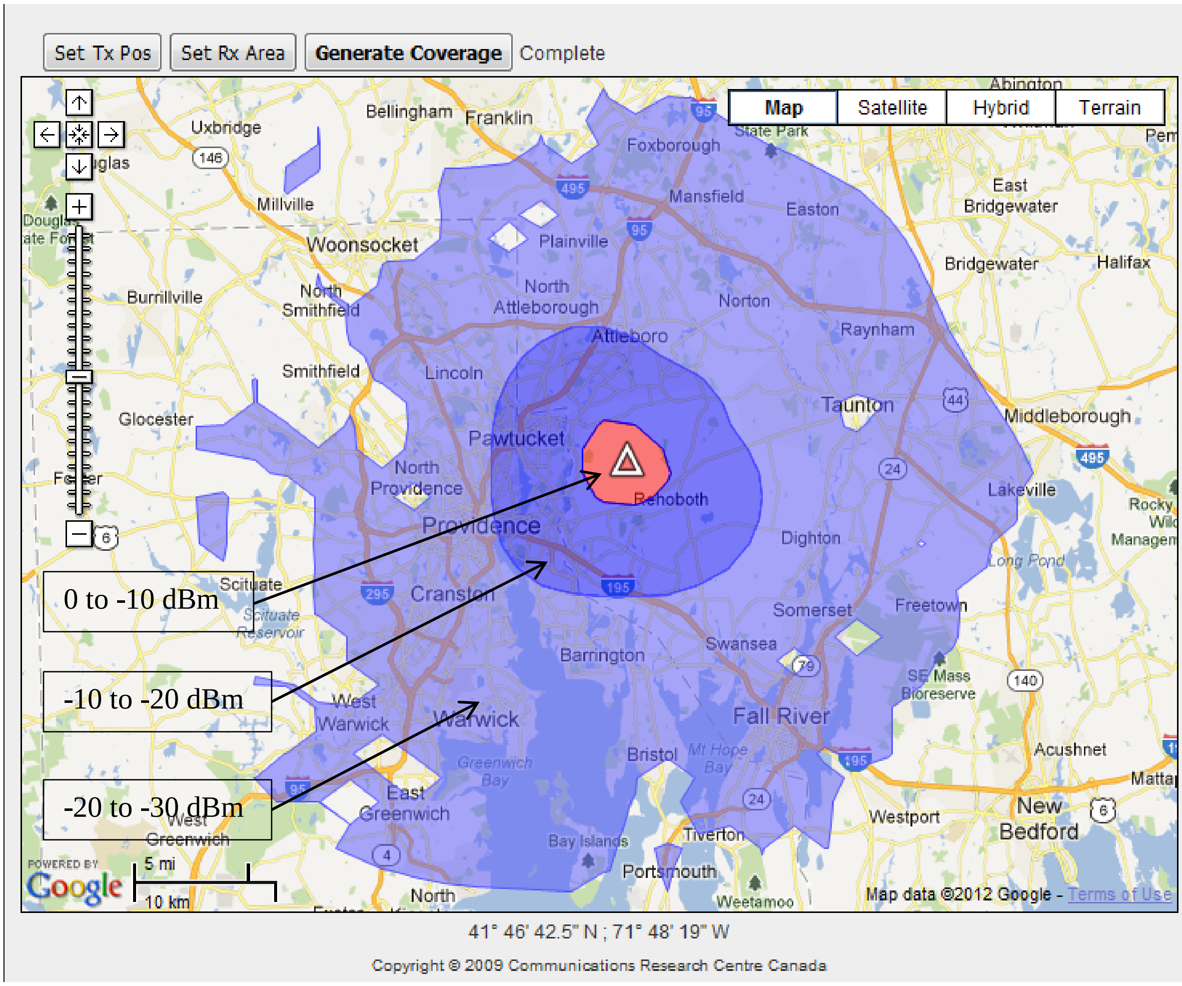
The red inner circle (approximately 14 sq. mi) represents areas where the Channel 51 signal measures 0 to -10 dBm; the dark blue represents areas (approximately 115 sq. mi.) where the Channel 51 signal measures -10 to -20 dBm, and the light blue (approximately 600 sq. mi.) represents Channel 51 signals of -20 to -30 dBm.

Some commenters have suggested that reverse intermodulation interference will only occur when the Channel 51 transmitter is located in a city, as opposed to on a mountaintop or in a rural area. Some Channel 51 transmitters are in less populated areas, but others are in highly populated areas even if they are not in a city. Figure 28 below shows the predicted signal levels from the Channel 51 DTV station located in Providence, Rhode Island. Vulcan stated that this transmitter is located in a rural area.[46] However, as the figure below shows, the area within which the station's signal will be at between -20 and -10 dBm covers 240 square miles, and includes parts of Providence and a large swath of I-95 between Pawtucket and Boston.[47]

46 *Ex Parte* Letter of Michele C. Farquhar, Counsel to Vulcan Wireless LLC, to Marlene H. Dortch, FCC, Attachment, AT&T-Qualcomm and the Need for a Consolidated Lower 700 MHz Band Class at 19, WT Docket No. 11-18 (filed Dec. 12, 2011).

47 Vulcan also notes that the Denver Channel 51 station has its transmitter on a mountaintop. *Id.* But the area within which the station is predicted to have a signal of between -20 and -10 dBm includes the city of Golden, Colorado as well as stretches of interstate highways.

Figure 28



Red: -10 to 0 dBm
Dark Blue: -20 to -10 dBm
Light Blue: -30 to -20 dBm

The red inner circle (approximately 27 square miles) represents areas where the Channel 51 signal measures 0 to -10 dBm; the dark blue represents areas (approximately 240 square miles) where the Channel 51 signal measures -10 to -20 dBm, and the light blue (approximately 1,800 square miles) represents Channel 51 signals of -20 to -30 dBm.

It is clear from these predicted power levels that there is a significant risk of harmful interference from reverse intermodulation were the Commission to mandate that Lower B and C block licensees use a Band 12 filter.

B. Interference Mitigation Strategies and Field Tests Discussed in the NPRM.

1. Reducing Gain State.

Qualcomm tested whether reverse intermodulation interference could be decreased through the lowering of device output levels, a potential mitigation strategy proposed by certain commenters.[48] Qualcomm's testing shows that linearity of the devices' power amplifier is not directly correlated to gain, and in any case, because a device may utilize any gain level at any given moment, the proposed mitigation strategy would not alleviate the reverse intermodulation problem described above.

In a real-world network deployment, mobile devices transmit over a range of output power levels. Manufacturers design power amplifiers to switch gain states (typically among three gain levels) so that devices do not transmit at maximum power at all times, but rather can transmit at the minimum necessary level under specific circumstances (distance from the base station, obstacles, etc.) in order to conserve energy and prolong battery life.

Qualcomm's testing indicates that consumer devices would experience harmful reverse intermodulation interference to varying degrees over all three gain states. In all of Qualcomm's measurements, this interference begins to be noticeable at received Channel 51 signal levels of approximately -20 dBm, and the resulting receiver desensitization increases as the Channel 51

[48] *See* NPRM, ¶ 35; *Ex Parte* Letter of David L. Nace, Counsel to Cellular South, and Thomas Gutierrez, Counsel to King Street Wireless, to Marlene H. Dortch, FCC, Attachment at 4, WT Docket No. 11-18 (filed May 27, 2011).

signal strength increases. The received Channel 51 signal must be below -25 dBm to ensure that reverse intermodulation interference does not affect device performance at all.

Qualcomm's testing further shows that non-linearity is often higher in lower gain states than in higher gain states. And in any case, devices could be in any gain state at any given moment. Thus, the more accurate assumption would be that devices could be susceptible to interference any time they are confronted with a Channel 51 signal at a level above -20 dBm. If a consumer's device happens to be in a gain state that is more susceptible to reverse intermodulation interference at the time it receives a higher Channel 51 signal, the consumer will experience call dropping or service degradation. If the Commission were to mandate that carriers use only phones with less susceptible gain states, the result would be a substantial loss of device efficiency. Furthermore, millions of devices already in the hands of consumers would remain unacceptably vulnerable to reverse intermodulation interference.

2. Vulcan's Study of Channel 51 Received Power Levels.

Vulcan conducted a field test to measure Channel 51 received power levels.[49] Based on this study, it reported that a minimum signal level of 0 dBm from Channel 51 would be necessary to create an interference signal at the noise floor of the B Block receiver, and that field tests it conducted measured Channel 51 transmissions that were no stronger than -21 dBm.[50]

Qualcomm found several flaws in Vulcan's study.[51] First, as discussed above in relation to Vulcan's E Block study, when conducting an interference analysis, engineers examine worst-case scenarios, such as where user equipment is located immediately adjacent to a potentially

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[49] *See generally* Vulcan Study, Attachment.

[50] *Id.* at 15.

[51] *See also* December 6, 2011 Qualcomm Ex Parte.

interfering transmitter, or in other geographical areas where consumer devices are vulnerable. Vulcan's study did not examine worst-case scenarios. In its field tests, Vulcan measured received signal from a high power (1 MW) DTV station near Atlanta, in Rome, GA.[52] It did not, however, measure the signal level of that DTV station any closer than 2 km from the transmitter. Because Channel 51 transmitters can be located in populated areas, understanding received power levels in close proximity to the transmitter is critical.

Second, Vulcan's test equipment was inappropriate for the intended measurements. The company used a vertical whip antenna to measure the signal from a DTV station using a horizontal polarized antenna. This technique would result in findings that substantially understate the signal strength of the DTV station, particularly in line of sight conditions, where the DTV signal strength would be highest.

Third, Vulcan used an unrecognized formula for predicting reverse intermodulation interference. In fact, there is not a recognized formula of measuring this type of interference, as revealed in a recent paper.[53] Because of this fact, Qualcomm tested reverse intermodulation using lab measurements rather than relying on an unrecognized and unsupported prediction method.

Fourth, Vulcan asserted in its study that Channel 51 signals would need to be at signal levels greater than 0 dBm for reverse intermodulation to occur. Qualcomm's tests suggest that this is not the case. Instead, harmful reverse intermodulation occurs at much lower Channel 51 received power levels, and the Band 12 filter does not provide sufficient rejection to protect the user equipment from harmful reverse intermodulation interference. In contrast, Band 17 devices

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[52] Vulcan Study, Attachment at 15.

[53] *See, e.g.*, Katz *et al.*, *supra* note 41, at 53 (One of the paper's co-authors is a member of the U.S. Army Research Lab).

can provide sufficient rejection of the Channel 51 signal to reduce the risk of harmful reverse intermodulation interference.

Fifth, when anticipating potentially interfering signals from adjacent power transmitters, industry practice is to apply a margin to measured signal levels to insure reliable service. These margins reflect the fact that actual power levels vary from the average measured power levels in part because of the constructive addition of multiple paths (*e.g.*, from signal reflection). As a result, industry engineers typically add 4 to 8 dB to average measured signal levels to account for this variation.[54] Vulcan did not include this margin in its study.

3. Separating LTE Base Stations and Channel 51 Transmitters Will Not Mitigate Harmful Interference.

Certain commenters suggested that intermodulation interference may be mitigated by the deployment of LTE base stations in close proximity to the Channel 51 stations (several hundred meters away) to control device transmit power and provide a stronger downlink desired signal.[55] Qualcomm has reviewed this proposal and finds that it will not alleviate the problems discussed above, essentially for the reasons discussed on pages 28-30, *supra*, in relation to a similar proposed mitigation strategy related to E Block interference.

B and C Block operators can address the near-far problem through base-station collocation because their base stations use similar power levels and aim to produce similar cell sizes. On the other hand, B and C Block operators cannot use base-station collocation to solve Channel 51 interference because Channel 51 transmitters operate at far higher power (1 MW)

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[54] *See, e.g.*, William C. Jakes, MICROWAVE MOBILE COMMUNICATIONS 79-133 (1974). Jack Damelin *et al.*, *Development of VHF and UHF Propagation Curves for TV and FM Broadcasting*, FCC Report No. R-6602 (Sept. 7, 1966), *available at* http://transition.fcc.gov/oet/info/documents/reports/R-6602.pdf.

[55] NPRM, ¶ 35.

and aim to produce very different coverage patterns. In addition, Channel 51 operators place transmitters in locations that will maximize DTV coverage area, but are likely to be inappropriate for B and C Block base stations. The areas of potential interference from Channel 51 are relatively large compared to typical wireless cell dimensions, which means that collocation, even if feasible, could only address the interference within a fraction of the area.

IV. QUALCOMM CONTINUES WORKING TO ADDRESS INTERFERENCE AND INTEROPERABILITY ISSUES WITHOUT FCC TECHNICAL MANDATES.

The NPRM asks if industry will provide a "timely" solution to interoperability in the Lower 700 MHz band, or whether regulatory mandates will be necessary.[56] Despite the interference challenges discussed above, Qualcomm has been, and continues to, work diligently to devise novel and innovative solutions that expand interoperability while recognizing the challenging interference environment. Such solutions are focused not on *reducing* choice by compelling certain licensees to use bands that are more susceptible to interference (and that they do not wish to use), but rather on *increasing* choice by allowing A Block licensees (just like any other licensee) to obtain chips that will cater to their needs *and* offer interoperability with other bands. Creative approaches to engineering and design now have provided significant steps forward in this regard. Given this reality, technical mandates that reduce choice risk stifling innovation, delaying future interoperability solutions, driving up costs, reducing network capacity, and harming the public interest.

The wireless market, from service to devices to chips and components, is hyper-competitive. Qualcomm strives, indeed races, to provide chips that support the most technologies and the most frequency bands, all at the least cost. If a Qualcomm OEM customer,

[56] NPRM, ¶ 47.

or a carrier deploying LTE or 3G anywhere in the world, requests a technical solution, Qualcomm aims to meet the request as quickly as possible within the constraints of Qualcomm's resources and competing business demands. Qualcomm—at its own initiative—has accelerated its development of next-generation solutions to provide technical solutions for Lower 700 MHz carriers, including Lower A Block licensees. These hyper-competitive market conditions obviate the need for any regulatory mandate.

A. Existing Chipsets Cannot Support Both Bands 12 and 17.

Qualcomm's current flagship RF chip, the RTR8600, is able to support Band 12, as well as the cellular, PCS, and AWS bands, all on one chip—which means that A Block licensees' devices using this chip support operations on not only the Lower 700 MHz A Block but also on other leading U.S. CMRS bands. Accordingly, in 2011, Qualcomm developed a commercial version of a chipset for the Lower A Block licensees that supports LTE, 3G, and 2G networks. This chipset, the MDM9600, includes the RTR8600 RF chip supporting Band 12, as well as the 850 MHz, PCS, and AWS bands.[57] The MDM9600, like all of Qualcomm's first-generation data chipsets, can be used in conjunction with a Qualcomm MSM chip in a phone or it can be used by

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[57] Qualcomm chipsets consist of MSMs (Mobile Station Modems), MDMs (Mobile Data Modems), and APQs (Application Processors). Both MSMs and MDMs are sold in conjunction with a Qualcomm RF chip. A Qualcomm RF chip, when built into a device in conjunction with an MSM or an MDM as well as filters and other parts not made by Qualcomm (including a power amplifier), enables the device to send and receive on various frequency bands. A Qualcomm MSM includes an integrated Qualcomm modem, which supports various wireless technologies (such as LTE, CDMA2000, HSPA, UMTS, etc.), and an integrated Qualcomm applications processor, which includes a central processing unit (CPU). A Qualcomm MSM enables voice and data connectivity. A Qualcomm MDM includes an integrated Qualcomm modem, but does not include a Qualcomm application processor. An MDM only supports data connectivity on its own. But a Qualcomm MDM can support voice as well if it is used in conjunction with a Qualcomm MSM. A Qualcomm APQ consists only of an application processor and must be used in conjunction with an MSM or MDM to provide voice or data connectivity.

itself in a data-only device. Qualcomm publicly announced the MDM9600 with support for Band 12 in April 2011, at the FCC's workshop on interoperability.[58] Qualcomm has delivered commercial samples of the MDM9600 with the RTR8600 supporting Band 12 since October 2011.

However, the RTR8600 cannot, without modification, support both Bands 12 and 17. That is because Qualcomm's chipsets are built with a limited number of "ports," each one of which supports a different frequency band or "path." The RTR8600's ports can support five 2G, 3G, or 4G paths, two of which can be lower 3G or 4G frequency bands—bands below 1 GHz, including the 3GPP-designated 700 MHz bands and the 850 MHz band. Because Block A operators typically require support for the 850MHz band in order to maintain backward compatibility, the RTR8600 does not have sufficient ports to support two additional 700 MHz bands, such as Bands 12 and 17.

Qualcomm has nonetheless offered a modified RTR8600 that could support a second 700 MHz band class, as well as the 850 MHz cellular band, by utilizing an external switch. Qualcomm informed A Block licensees, however, that an external switch would degrade performance of the device. Consequently, no Lower A Block operator was interested in this modified RTR8600.

B. Qualcomm's Next-Generation Chipset Offers Support for An Additional Band Below 1 GHz.

As part of its ongoing work to provide support to all carriers and their OEMs, including in technically challenging bands, Qualcomm has continued its development of innovative RF

58 Presentation of Michael Chard, Qualcomm Inc., FCC 700 MHz Interoperability Workshop, at 6 (Apr. 26, 2011) (http://transition.fcc.gov/presentations/04262011/michael-chard.pdf).

chips and integrated LTE-3G-2G chips in an effort to support as many bands and "address interoperability concerns without regulatory intervention and within a reasonable timeframe."[59]

Qualcomm currently plans to release commercial samples of the MSM8960 chipset with the companion next-generation RF chip, the WTR1605L, which supports Band 12, in July of this year. The WTR1605L supports more ports than did the older RTR8600; specifically, devices using these WTR1605L-containing chipsets will be capable of supporting up to three low bands (below 1 GHz), as compared to two low bands on the RTR8600, along with three high bands (above 1 GHz) and one very high band (2.5 GHz). This will provide Lower A block licensees using Band 12 with access to another 700 MHz band for roaming, including Band 13 or Band 17, as well as Band 25 (the PCS G Block), in addition to the cellular, PCS, and AWS bands for 3G operations, provided that the necessary software and the necessary additional filters, which are not made by Qualcomm, are added by device manufacturers.

To do so, device manufacturers would use a technique known as "band-stitching" to enable support for these bands (Bands 13 or 17, and/or 25). For this technique, Qualcomm would provide the device manufacturer with software code supporting the additional band or bands that the carrier requires, based on the carrier's specific preference (which may change depending on each carrier's roaming agreements and as LTE is deployed on new spectrum bands). The OEM, in turn, would be responsible for integrating the additional band(s), adding any necessary filter or filters and performing the necessary testing.

Moreover, Qualcomm also plans to provide Band 12 support on its upcoming new LTE-3G-2G data chip, the MDM9615, with commercial samples available in July of this year. This chip can be used for dongles and other data devices. When paired with an MSM chip, it can

[59] NPRM, ¶ 49.

provide a smartphone with a two-chip LTE-3G-2G solution enabling both voice and data on Band 12. Finally, the new MSM8930, another chip for smartphones with integrated LTE support, will include Band 12 support. Qualcomm expects that commercial samples of the MSM8930 will be available in August of this year. Both the MDM9615 and the MSM8930 will be capable of supporting the various RF configurations outlined above, including (through band stitching) the ability to support Bands 13 or 17 and/or 25, if coupled with the WTR1605L.[60]

Given these technological developments, a regulatory interoperability mandate is unnecessary. The new WTR1605L-based chips will provide Lower A block licensees with interoperability with any LTE band (or bands) they wish, subject to the limitations of existing technical solutions and to marketplace capacity issues.[61] And importantly, these chips would allow interoperability without exposing the licensees of other blocks to the very substantial risks of harmful interference from E Block and Channel 51 operations that are outlined above and that a Band 12 filter could not alleviate.

C. Band Stitching Provides Interoperability But Not Seamless Roaming.

Even with the advances of the WTR1605L chip and band stitching, more innovation still must be completed before seamless interoperability is technically possible. Band stitching requires OEMs to upload multiple software modules supporting different bands onto a single hardware configuration to "stitch" chip configurations together to support multiple bands that are not included in a single configuration. However, band stitching will not support seamless

[60] Operators may need to make additional network equipment changes in order to support such roaming. Those changes—and the associated time and resources required—are beyond the scope of these comments.

[61] Qualcomm currently faces capacity constraints on its ability to provide new 28-nanometer chips, such as the MSM8960, MDM9615, and MSM8930. As a result, while this capacity constraint continues, Qualcomm is obligated to continue to supply RTR8600-based chips for which this band stitching will not be possible.

roaming within a call (all calls over LTE are data calls currently because Voice-Over LTE has not yet been deployed). Qualcomm does not have a technical solution at this time that would support seamless roaming between Band 12 and another LTE roaming band, and even if it did, compatibility issues between different carrier networks likely would create additional obstacles to seamless roaming.

D. Qualcomm's Band 12 Blocking-Reduction System Offers E Block Blocking Interference Mitigation, but Greatly Reduces Device Performance, and Does Not Mitigate Intermodulation Interference.

The Qualcomm chips supporting Band 12 do not resolve the interference threats described in these comments. But Qualcomm has devised a Band 12 blocking-reduction system offering partial solution for A Block licensees facing E Block blocking interference. This partial solution, which is not part of the 3GPP standard, works in the modem (not the RF chip) to reduce the threat of harmful blocking interference from Channel 56 for Band 12 user equipment, but, importantly, cannot address either intermodulation interference from Channel 56 or reverse intermodulation interference from Channel 51.[62] When deployed, this solution effectively attenuates a Channel 56 signal more than does a normal Band 12 filter (although less than a Band 17 filter), allowing operation without blocking in an environment with an E Block signal of up to -30 dBm.

But this protection comes with a significant reduction in receiver sensitivity. Therefore, although this solution reduces blocking interference caused by the E Block, it also severely degrades device performance, resulting in performance that is inferior to that of devices using a Band 17 filter. The result is that while a Band 12 receiver using the Band 12 blocking-reduction

[62] Because this Band 12 blocking-reduction system does not derive from the 3GPP (or any other) standard, similar technologies from other manufacturers will differ in their performance.

system can avoid an E Block blocking interference in some additional situations where it would now suffer interference, this system may also render the device unable to receive a signal near the edge of its coverage due to receiver degradation. When a high-power E Block transmitter is present, the Band 12 receiver using the Band 12 blocking-reduction system will experience approximately 11 dB in degradation in receive capability compared to a Band 17 receiver because the Band 12 blocking-reduction system increases the internal noise in the device.

Critically, the Band 12 blocking-reduction system also will not mitigate E Block intermodulation interference or Channel 51 reverse intermodulation interference. As a result, even if a device was equipped with the blocking-reduction system, it would continue to suffer harmful interference from E Block signals in every city with an active signal on the E Block and from Channel 51 signal—and would be further burdened by the 11 dB desensitization discussed above. Therefore, while this might be the only viable solution now for A Block licensees looking to deploy service in markets without a Channel 51 DTV station so that they can achieve at least some E Block protection, it is clearly unacceptable for a B or C Block licensee because of its substantial inferiority in both receiver performance and interference mitigation as compared to the Band 17 filter as to interference from both the E Block and Channel 51.

V. ANY COMMISSION INTEROPERABILITY MANDATE FOR THE LOWER 700 MHZ BAND WOULD IMPOSE SIGNIFICANT BURDENS ON THE WIRELESS INDUSTRY AND LEAD TO DELAYS IN LTE DEPLOYMENT.

A Commission mandate requiring interoperability across the Lower 700 MHz band would lead to consumer device degradation, create significant burdens, require at least a two-year transition period, and delay deployment of other wireless technology like carrier aggregation.

A. Consumer Device Degradation.

As Qualcomm's analysis demonstrates, consumer device performance will be detrimentally affected, sometimes devastatingly so, in regions where E Block or Channel 51 operations are present. This degradation, although localized for a given E Block or Channel 51 transmitter, is likely to occur in many regions of the country and is likely to significantly affect customers as they travel around the country, and requiring operators to use Band 12 devices would condemn Band 17 devices to inferior service and dropped calls. Band 17 exists for a very good reason. While Band 12 must be a limited regional service because it is unable to operate in areas where the E Block or Channel 51 is active, Band 17 allows carriers to serve consumers anywhere in the country.

B. A Mandate Would Require At Least A Two-Year Transition Period and Would Delay the Roll Out of Other Important Technologies.

A Commission interoperability mandate eliminating Band 17 would impose significant costs and operational constraints on Qualcomm. First, Qualcomm expects several of its OEM customers to launch Band 17 devices based on the existing RTR8600 chip throughout this year and next year. OEMs already have invested significant resources in research and design to create those devices, which they hope to recoup through a device's success in the market. Qualcomm has obligations to supply RTR8600 chips to those OEMs. Devices launching this year will have a lifespan of up to three years—through 2015. A mandate eliminating Band 17 would strand these devices in the launch pipeline, leaving Qualcomm unable to meet its performance obligations, OEMs unable to bring devices to market or to recoup any of their design investment, and consumers without access to innovative new devices. Additionally, any mandate eliminating Band 17 would subject consumers to the significant, unresolved interference issues described in these comments.

An alternative dual-band mandate requiring every phone to support both Band 12 and Band 17 is undesirable because it is arbitrary given the number of other possible band combinations and the fact that current RF chip technology remains port-constrained. The Band 12/17 combination is merely one of many band combinations that carriers may choose to serve their customers and increase interoperability. Carriers can choose, depending on chip port availability and their respective roaming agreements, to offer devices that combine a wide array of 4G band combinations—including any of the following:

- 700 MHz 3GPP bands (Band Classes 12, 13, 14, 17);
- 850 MHz cellular band (Band Class 5);
- Original PCS band (Band Class 2);
- PCS Block G (Band Class 25);
- AWS-1 band (Band Class 4);
- Potential AWS-4 band (Band Class 23);
- Original 800 MHz iDEN band (Band Class 26); and
- BRS band (Band Class 41).

It would be inappropriate for the FCC to force all carriers to choose the Band 12/17 combination when in fact they might determine that another band combination is superior. As discussed above, Qualcomm's next-generation WTR1605L RF chip, remains port constrained – it can support only three low bands. A mandate requiring carriers to support Bands 12 and 17 would therefore force carriers to use two of the three ports for Band 12 and 17, thereby precluding other desirable band configurations.[63]

If, nonetheless, the Commission imposed an interoperability mandate requiring every device to support both Band 12 and Band 17, Qualcomm could comply only through extensive, time-consuming work with every OEM customer serving U.S. carriers to ensure that each company transitions from its current chipsets to the WTR1605L and implements band

[63] For backwards compatibility reasons, carriers would almost always request that the third port support cellular frequency.

stitching.[64] This would take at least two years. Qualcomm would require this transition period because, first, OEM customers would have to relaunch existing user equipment, and the new combinations of chipsets and OEM hardware would force companies to redesign many products because of the physical differences between the RTR and the WTR chipsets. OEMs would also have to create new and unexpected software-hardware intersections. This redesign process would take nine to twelve months. Following this work, Qualcomm, OEMs, and carriers would have to test all the new technology. Each configuration of band—*e.g.*, Band 12 and Band 17—between carriers would require individual testing to identify and resolve issues with each carrier's unique network design. None of this testing work could begin until all affected carriers had roaming agreements in place with their desired partners, a process that can take significant time. Based on prior experience, Qualcomm anticipates testing between any two carriers, once roaming agreements were in place, would take up to three months. Importantly, the time and difficulty described above concerns only tasks related to chip and technology design and manufacture—it does not include the substantial work carriers must complete, which will add time and complexity.

If the FCC were to mandate a technology-specific approach to interoperability that is inconsistent with band stitching with the WTR1605L, Qualcomm would face an even more exceptional set of problems and costs, and would not be able to comply even with a two-year transition period. Because the WTR1605L plus band stitching approach is the only interoperability approach about to become available, the company would have to begin a research and development process to redesign a completely new platform. This alone could take

[64] Some user equipment already in commercial use would continue to require the RTR-series chipset that support 3G and 2G. This is particularly important for carriers that have not yet deployed LTE networks and continue to require 3G-2G chips for cellular, PCS, and AWS, until they launch LTE.

at least 12 months, and could create uncertainty throughout the wireless industry. Once completed, OEM customers would have to go through their own redesign process to accommodate any physical changes in chipsets, and implement software/hardware connections, before testing devices with carriers.

The time and resources required to satisfy any technology-specific mandate would delay development and deployment of other wireless technologies while Qualcomm, OEMs, and carriers diverted limited resources to meet a mandate's requirements. Because of these extreme costs and burdens, Qualcomm urges the Commission to avoid a technologically-specific interoperability mandate that would prevent band stitching.

An interoperability mandate would also require Qualcomm, along with OEMs and carriers, to divert resources away from current and planned projects, which are also a high priority for the wireless industry, including for carriers who own A Block spectrum. For Qualcomm, this would require redirecting technical and field testing personnel from priority projects such as carrier aggregation[65] for a period of at least six to nine months while providing support to OEMs and carriers on meeting an interoperability mandate. A mandate therefore would delay Qualcomm's ability to roll out carrier aggregation and defer the increased spectrum efficiencies it offers to carriers, especially those with smaller spectrum holdings.

VI. CONCLUSION.

Qualcomm is working hard to design chipsets that support the entire Lower 700 MHz band, mitigate interference, and improve interoperability. But the Lower 700 MHz band presents

[65] *See*, *e.g.*, Julius Genachowski, Chairman, FCC, Prepared Remarks at International CTIA Wireless 2012 (May 8, 2012) (http://hraunfoss.fcc.gov/edocs_public/attachmatch/DOC-313945A1.pdf).

unprecedented interference challenges. Without proper filtering, a consumer device operating on the B and C Blocks would suffer blocking interference from E Block signals, intermodulation interference when the E Block signal combines with its transmit signal, and reverse intermodulation interference because of TV Channel 51.

Qualcomm has not found an acceptable solution to these interference challenges. Furthermore, unfortunately, the mitigation techniques suggested by A Block licensees will not work and studies purporting to show that these interference concerns are manageable are deeply flawed. Consequently, the Commission should find that harmful interference from both the E Block and Channel 51 would unacceptably degrade consumer devices operating in the B and C Bands without the Band 17 filter in place.

Despite these challenges, Qualcomm continues to innovate, and, as described herein, has created novel technological advances to improve the situation for A Block licensees. But the company still does not have an interoperability solution that protects consumers from harmful interference—and creating one, if this outcome were mandated by the Commission, would take years, increase costs, and still yield consumer device degradation. The FCC therefore should not mandate that all devices be capable of operating across the entire Lower 700 MHz band, much less the entire Upper and Lower 700 MHz band.

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